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QUARTERNARY FAUNAS IN THE ST. JONSFJORD — EIDEMBUKTA REGION, VESTSPITSBERGEN

BY

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Abstract. The paper lists occurrences of Quarternary faunas in raised beach deposits from the St. Jonsfjord-Eidembukta region of Vestspitsbergen. The faunas from the deposits in the fjord are, in some respects, different from those of the west coast. The vertical distribution of species shows some approximation to that recorded by FEYLING-HANSSEN and JØRSTAD (1950) in the Sassen area. *Mytilus edulis* in abundance is recorded from the lower levels of the west coast.

Acknowledgment

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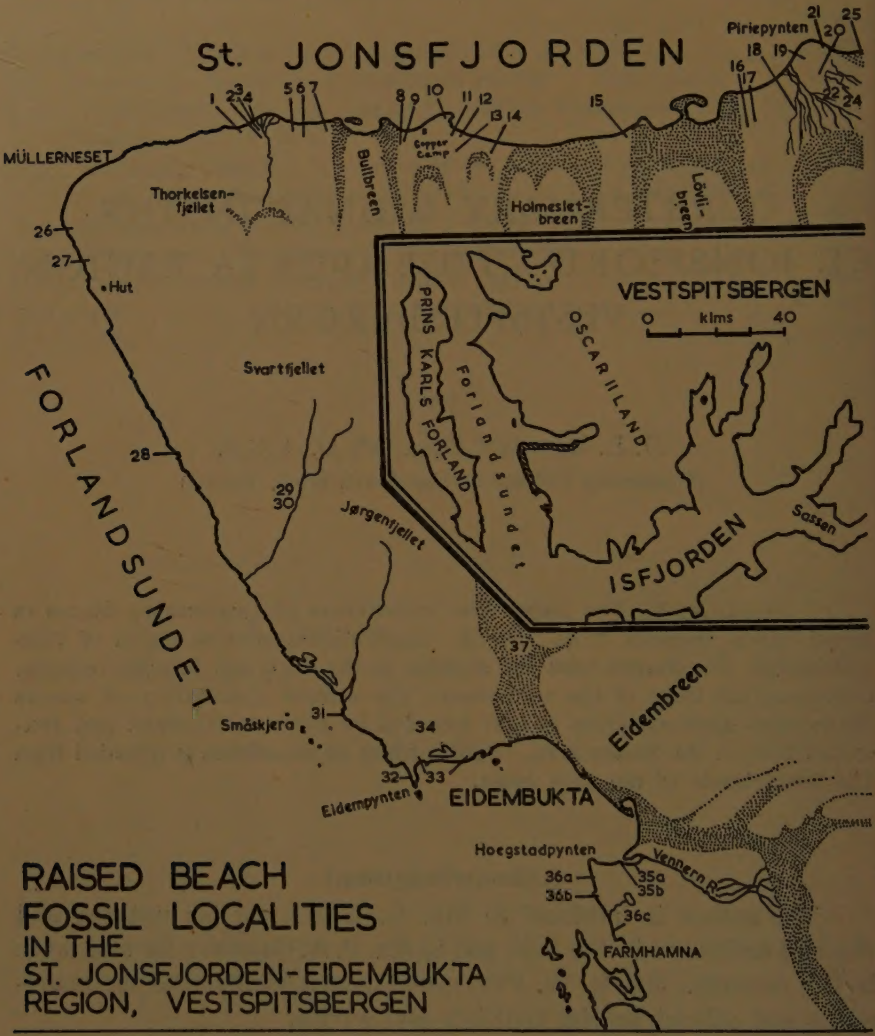

RAISED BEACH FOSSIL LOCALITIES IN THE ST. JONSFJORDEN-EIDEMBUKTA REGION, VESTSPITSBERGEN

Introduction

As a result of their work in the Sassen area of Isfjorden, Vestspitsbergen, R. W. FEYLING-HANSSEN, and F. A. JØRSTAD suggested (1950) that there may be a real possibility of correlating raised beaches by their included faunas. In the Sassen area several horizons within the raised Quarternary marine (littoral) deposits are marked by the dominance of certain fossils. PEACH (1916) had noted the abundance of *Saxicava arctica* in deposits bewteeen 15 and 21 m. above sea level on Prins Karls Forland and gave them the name «Saxicava Beach», but the fossil is by no means limited to the deposits between these two levels. The common fossils in the Sassen region are *Astarte borealis* (Chemnitz), *Mya truncata* Linne, *Saxicava arctica* Linne, and *Mytilus edulis* Linne. They are present at almost all levels, but their frequency varies so as to make possible the recognition of certain faunal horizons:

4. *Saxicava-Mya* horizon, average height above sea level 45 m.
3. Upper *Astarte* horizon, —«— 20.5 m.
2. *Lower Astarte* horizon, —«— 7 m.
1. *Mytilus* horizon, —«— 3.6 m.

Grouped broadly into: — *Astarte* division, 7.0 m. to 20.5 m.
Mya division, 20.5 m. to just below 45.0 m.[1]

A semi-recent level with abundant *Saxicava arctica* and *Lithothamnion* was identified and it was noted that whale bone was found between (but not below) 2 and 5 m. above sea level. FEYLING-HANSSEN and JØRSTAD remarked that the conditions which prevailed within the reaches of Isfjorden during post-glacial times may not have been operative on the western coast of Vestspitsbergen, and that the nature and sequence of the raised beach faunas in the west might be different from those within the fjord.

The Birmingham University Spitsbergen Expedition of 1951 collected raised beach fossils from the southern side of St. Jonsfjord and between Müllerneset and Farmhamna. The preservation of the raised features in the fjord is poor; distinct shore-lines or terraces on the strandflat are rare, the very gentle slope of the platform being covered with an almost continuous spread of shingle. A brief account of the raised marine features of this region has been given by the present writer (DINELEY, D. L., 1953). Time did not allow extensive collecting of the molluscan faunas from these deposits and the present treatment of the evidence cannot be regarded as statistical, but certain conclusions concerning the raised beach faunas of this area seem to be warranted.

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[1] In a letter dated 10 October, 1953, FEYLING-HANSSEN tells me that later investigations in the inner parts of Isfjorden showed that the *Astarte* division should be extended to somewhere above 30 m. and the *Mya* division to about 60 m.

There are numerous references in literature to the raised deposits of the west coast of Vestspitsbergen, but only Peach (1916) has made a study of the raised deposits and Quarternary faunas of the Forlandsund region. There is no general synthesis known to the writer which gives an account of the raised faunas of the entire west coast, and Feyling-Hanssen and Jørstad's work appears to be the only attempt on a detailed scale to establish palaeontological zones in the Quarternary sediments.

List of fossil localities

Height above m.s.l. is shown before each locality listed.

a = species abundant: more than 50 specimens collected from a few square yards of deposit within a few minutes' searching.

c = species common: about 25 specimens collected as above.

r = species rare: about 10 specimens collected as above.

Where very rare, the number of specimens found is given.

A. St. Jonsfjorden.

1. 18 m., 117 m. west of river gorge to east of Thorkelsenfjellet, in fine shingle.

Mya truncata	a

2. 24 m., 27 m. west of river gorge in loc. 1.

Mya truncata	a
Astarte sp.	c

3. 13.5—15 m. at foot of bank of fine shingle below loc. 2.

Mya truncata	c
Astarte borealis	c

4. 19.8 m. bank of coarse shingle 18 m. north of loc. 3.

Mya truncata	c
Saxicava arctica	c
Astarte borealis	r
Gastropod indet.	1 specimen.

5. 9—10.5 m. several bands of shingle between river delta and loc. 7.

Mya truncata	c
Saxicava arctica	c
Astarte borealis	r

6. 15—18 m. several banks of shingle above loc. 5.

Mya truncata	c

7. 10.5—12 m., 18—22.5 m. west of lateral moraine of Bullbreen.

Mya truncata	a
Saxicava arctica	c
Astarte borealis	c
Astarte montagui	r
Chlamys islandicus	4 specimens.

8. 30 m. bank of fine shingle in stream section immediately east of eastern lateral moraine of Bullbreen.

Mya truncata	a
Saxicava arctica	r

9. 28.5 m. immediately below loc. 6.

Mya truncata	a
Saxicava arctica	c
Astarte elliptica	r
Balanus balanus	3 specimens.

10. 4.5 m. bank of gravel due north-east of Copper Camp.

Mytilus edulis	10 specimens
Cyprina islandica	3 specimens

11. 4.5 m., 90 m. south south-east of loc. 10 (several exposures).

Astarte borealis	c
Mya truncata	r
Astarte elliptica	r
Cyprina islandica	5 specimens

12. 6 m. sand bank 9 m. due east of loc. 11.

Mya truncata	c

13. 7.5 m. mud polygons at top of cliffs due north of copper mine.

Mya truncata	c
Saxicava arctica	r

14. 15 m. shingle with large boulders immediately east of large corrie west of Holmesletbreen.

Mya truncata	c

15. 3.6—4.5 m. shingle beneath moraine at northern tip of western Løvlibreen lateral moraine.

Mya truncata	c
Saxicava arctica	r
Mytilus edulis	2 specimens
Astarte sp.	1 specimen.

16. 27 m. shingle bank emerging from beneath eastern lateral moraine of Løvlibreen.

Mya truncata	c
Saxicava arctica	r

17. 24 m. immediately below loc. 16.

Mya truncata	c
Astarte borealis	r
Saxicava arctica	6 specimens

18. 24 m. gravel bank on western side of large outwash fan to south of Piriepynten.

Mya truncata	c
Gastropod indet.	1 specimen.

19. 18 m. shingle on western slope of Piriepynten.

Mya truncata	c
Chlamys islandicus	1 specimen

20. 4.5 m. gravel on the southern side of Piriepynten.

Astarte borealis	a
Astarte montagui	c
Mya truncata	c
Saxicava arctica	c
Astarte elliptica	r
Lithothamnion sp.	r
Annelid tubes	r

21. 3 m. gravel on eastern side of Piriepynten.

Mya truncata	c

22. 3 m. shingle at south-western corner of small lake south of Piriepynten.

Mya truncata	c

23. 3—4.5 m. fine shingle in dry stream course, 4.5 m. north of loc. 22.

Mya truncata	c
Astarte borealis	c
Astarte montagui	7 specimens.

24. 3 m. shingle at south-eastern corner of lake mentioned as loc. 22.

Astarte borealis	a
Mya truncata	c
Saxicava arctica	c
Astarte montagui	r
Cyprina islandica	r
Annelid tubes	r

25. Up to 9.5 m. black shingly mud at northern extremity of western lateral moraine of Charlesbreen.

Astarte borealis	a
Astarte montagui	c
Mya truncata	c
Saxicava arctica	c
Astarte elliptica	r
Lithothamnion sp.	r

B. Müllerneset to Farmhamna.

26. 2.4—3 m. flaky gravel on crags at southern end of Müllerneset beach.

Mytilus edulis	a
Mya truncata	r

27. 3—4.5 m. several exposures of gravel on top of crags between loc. 26 and Müllerneset Hut.

Mytilus edulis	a
Mya truncata	r
Gastropod indet.	1 specimen.

28. 6.4 m. gravel on top of cliffs due south-west of Svartfjellet.

Mytilus edulis	c
Mya truncata	r

29. 30—36 m. banks of braided stream flowing from large corrie between Svartfjellet and Jørgenfjellet, fine shingle.

Mya truncata	c
Saxicava arctica	c
Astarte montagui	r
Mytilus edulis	r
Balanus sp.	1 specimen.
Whalebone	several large bones.

30. 24—27 m. same section as loc. 29.

Mya truncata	c
Saxicava arctica	c
Mytilus edulis	r
Buccinum glaciale	1 specimen.
Gastropod indet.	1 specimen.

31. 3.6—6.4 m. gravels above shore immediately opposite Småskjera.

Mytilus edulis	a
Whalebone	several large fragments.

32. 4.5—6 m. gravels on wave-cut bench immediately north of and on Eidempynten. Several exposures.

Mytilus edulis	a
Mya truncata	r
Astarte spp.	several fragments.

33. 3.6—6.4 m. gravels along north-west coastline of Eidembukta.

Mytilus edulis	c
Mya truncata	r
Astarte spp.	r

34. 7.5—10 m. fine shingle west of Eidem moraine.

Mytilus edulis	c
Mya truncata	r
Whalebone	several fragments.

35. 4.5—6.4 m. gravels resting on wave-cut bench between mouth of Vennern river and Hoegstadpynten (a. and b.)

Mytilus edulis	a
Saxicava arctica	c
Astarte borealis	r
? *Balanus balanus*	r
Mya truncata	r
Astarte sp.	several specimens.

36. 4.5—6.4 m. thick gravels resting on wave-cut bench on eastern side of Farmhamna (a, b, c.).

Astarte borealis	c
Lithothamnion sp.	c
Mytilus edulis	c
Saxicava arctica	c
Mya truncata	r
Spirorbis sp.	r

? *Balanus balanus*	several specimens.
Gastropod indet.	4 fragments.
Chlamys islandicus	3 specimens.

37. 49.5 m. Eidembreen moraine below Jørgenfjellet.

Mya truncata	c
Astarte borealis	c
Astarte sp.	r
Buccinum glaciale	8 specimens.
Gastropod indet.	2 specimens.

Discussion

(a). St. Jonsfjorden.

The raised features within the fjord fall topographically into five groups, at 3.6—4.5 m., 7.5—10 m., 12—21 m., 30 m. and at about 45 m. above sea level (see DINELEY, D. L., 1953, p. 505). The highest level at which fossils have been found is 30 m., which is low in comparison with other parts of Vestspitsbergen but not surprising in view of the poor state of preservation of the raised features within the fjord. Of the localities listed all except numbers 13 and 25 are upon marine shingle or silty mud. In the western lateral moraine of Charlesbreen (locality 25) fossils occur in a black plastic mud. It is clear that the glacier here has incorporated into its moraine marine deposits that lay in its path during its last major readvance, though whether these deposits were then ancient or recent (i. e. were raised or not prior to the last readvance of the ice) has not been determined. (See LAMPLUGH, G. H., 1911, and HEINTZ, A., 1953).

The number of fossil types discovered in the raised sediments during the present work is not great. Further searching would doubtless have extended the lists of species found. The fjord faunas are dominated by *Mya truncata* with *Saxicava arctica* second in importance; the other forms are much less frequent. *Mytilus edulis* is notably absent from most of the deposits, being found at only two low horizons. The *Mya* communities are interesting, several thousand individuals occurring together in a good state of preservation, usually in a fine grey or black silt. Presumably this is the sediment in which the animals burrowed. Many of the *Mya* shells are encrusted with annelid tubes and algal

St. Jonsfjorden. Table I.

	above m.s.l.				
	3.6 — 4.5 m.	7.5 — 10 m.	12 — 21 m.	30 m.	45 m.
Astarte borealis (Chemnitz)	c	a	c	r	—
Astarte elliptica (Brown) . .	r	r	r	r	—
Astarte montagui (Dillwyn)	r	r	r	—	—
?*Balanus balanus* (Linne) . .	r	r	—	3	—
Buccinum glaciale (Linne)	—	r	—	—	—
Chlamys islandica (Müller)	r	—	—	—	—
Cyprina islandica (Linne)	r	r	—	—	—
Mya truncata (Linne)	a	a	a	c	—
Mytilus edulis (Linne)	r	r	—	—	—
Saxicava arctica (Linne) . .	r	c	r	r	—

r = rare, c = common, a = abundant (as indicated previously).
Frequency of molluscs in the raised marine deposits of St. Jonsfjorden.

growths, many have suffered extensively the ravages of shell-boring organisms, and many show an enormous thickening. The latter is common enough to appear almost as a pathological feature. Some specimens still retain traces of the periostracum and ligament. The adult specimens often attain great size (8 cms by 5.25 cms being recorded) and show a considerable variation in shape, with a tendency for the variety *uddevalensis* to predominate, although the whole range from *ovata* Jensen to *uddevalensis* Hancock is represented.

The abundance of *Mya truncata* in the raised deposits of the fjord and the comparative scarcity of this fossil in those on the strandflat seems to suggest that it found, as would be expected, a more favourable environment in the quiet waters of the fjord than in the more agitated sea of Forelandsundet. FEYLING-HANSSEN and JØRSTAD (1950, p. 49) suggested that the ecological conditions on the west coast of Vestspitsbergen are quite different from those in Isfjorden and thus different from those in similar fjords, and this must have been so during the formation of the raised beach deposits also. The fjord waters today, while generally calm, are muddy, and the influx of glacial mud at the time when those deposits were accumulating was probably much the same as it is today: on the other hand, the sea in Forlandsundet is more free from suspended matter. The distribution of the fossils *Mya truncata* and *Mytilus edulis* may have been affected by such conditions. NATHORST (1901) has stated that *Mytilus* cannot possibly live in the immediate neighbourhood of a productive (= calving?) glacier, and the presence of that fossil in the lower raised sediments has been taken to indicate that they accumulated under warmer conditions than those of today. (FEYLING-HANSSEN and JØRSTAD have discussed the inadvisability of retaining the term «*Mytilus* period», at least while our knowledge is in its present state). Since *Mytilus* is replaced by *Mya* in the fjord deposits, one may assume that the fjord waters were at least as muddy and probably as cold or colder than they are at present.

(b). The East coast of Forlandsundet (Müllerneset to Farmhamna).

The raised deposits below about 45 m. on the strandflat of the eastern side of Forlandsundet consist of shingles, sands, muddy silts and gravels. Above 45 m. in this area they are poorly preserved, and occur as isolated patches of pebbles or coarse shingle from which no faunas have been obtained. Here even more than in the fjord there is a serious difficulty in ascribing the fauna to a particular level or terrace. This arises from the redeposition of sediments and fossils from terraces at greater heights. As FEYLING-HANSSEN and JØRSTAD (1950, p. 11.) point out, the upper terraces have produced the greater part of the material from which those beneath are composed: faunas may in this way become mixed and confusion in correlation may result. They quote the instance of *Mytilus edulis* which is now found on the modern shore in Isfjorden — as it is in Forlandsundet — yet this mollusc does not live in Isfjorden today; its shells have been washed down from the raised deposits.

The striking characteristic of the lowest deposits in the present region is the dominance of *Mytilus edulis* in the included fauna. *Mytilus* occurs in great numbers in the thick deposits of shingle and sub-angular gravel resting on the cliff tops, often to a height of 12 m. or more. The gravels in which the fossils occur are different from those above in that they consist largely of locally derived Hecla Hook slaty material, not quartzitic shingle. The shells themselves are very broken and comminuted and are so numerous that a shell sand often results; comparatively

Müllersneset to Farmhamna. Table II.

	above m.s.l.				
	3.6—4.5 m.	7.5—10 m.	12—21 m.	30 m.	45 m.
Astarte borealis (Chemnitz)	c	c	r	r	—
Astarte elliptica (Brown) ..	r	r	—	—	—
Astarte montagui (Dillwyn)	c	r	r	—	—
?Balanus balanus (Linne) ..	c	r	r	r	—
Buccinum glaciale (Linne)	r	r	r	—	—
Buccinum sp.	r	—	—	—	r
Chlamys islandica (Müller)	r	r	r	—	—
Cyprina islandica (Linne)	r	r	r	—	—
Mya truncata (Linne)......	c	c	c	c	c
Mytilus edulis (Linne)	a	a	c	r	—
Saxicava arctica (Linne) ..	c	c	c	c	r
Lithothamnion sp.	a	c	r	—	—
Spirorbis sp.	a	a	c	c	r

r = rare, c = common, a = abundant (as indicated previously).
Frequency of fossil species found in the raised marine deposits between Müllersneset and Farmhamna.

few complete shells were found below 5.4 m. Rapid and turbulent deposition (possibly of material derived from the raised shingles immediately above as well as of fragments thrown up by the waves) followed by rapid uplift is suggested to account for these sediments. The absence of large masses of shingle down-washed from above has been noticed and it seems unlikely that all the *Mytilus* fragments could have been selectively sorted and washed from the higher deposits: the majority of the shells must have been thrown up by the waves, and the application of the term «*Mytilus* terrace» seems to be justified. Prior to FEYLING-HANSSEN and JØRSTAD'S work in the Sassen area *Mytilus* terraces had not been recorded in Svalbard. In Sassenfjorden the average level of these terraces is 3.6 m. which seems to correspond to the group of levels between 3.6 m. and 6.4 m. near Müllerneset and around Eidembukta. Although (poor) *Mytilus* communities existed at Sassen in the inner reaches of the fjord, conditions on the west coast, with the prevailing warm westerly currents, must have been more congenial, and it is possible that *Mytilus* terraces will be found extensively on the west coast.

Above the *Mytilus*-crowded sediments that fossil persists to a height of at least 30 m. but becomes increasingly rare. Up to the 30 m. level *Mya truncata* and *Saxicava arctica* are common forms, but above this level fossils are very scarce. Whalebone has, however, been found at 36 m. *Astarte borealis* is rare within the 12—21 m. group of deposits, and extremely rare above it; the scarcity of the fossil above the 21 m. mark seems to correspond to the upward limit of extensive numbers of this shell in the Sassen areas (20.5 m.) and other parts of Vestspitsbergen.

Conclusions

The collections of raised beach fossils made within the St. Jonsfjord —Eidembukta region could, no doubt, be greatly extended by intensive search, but several features are already worthy of note. In the fjord the thick-walled molluscs predominate: *Mya truncata* is present in abundance in deposits up to 21 m. or so, while *Mytilus edulis* is represented only by a few specimens at only the lowest levels. In the deposits of the strandflat the latter fossil is most prolific in deposits up to 12 m., whereupon *Mya truncata* takes its place. *Saxicava* seems to be common between 12 m. and 21 m., but it is hard to see how a «*Saxicava* beach» could be distinguished in this part of Vestspitsbergen on the evidence collected. (The author has not yet visited Prins Karls Forland where Peach (1916) originally recognised his «*Saxicava* beach».)*Astarte borealis* is common in both raised fjord and strandflat deposits up to about 12 m.

Discussing PEACH's work, FEYLING-HANSSEN and JØRSTAD (p. 43.) comment that if that author had traced really contemporaneous beaches over the wide area that he claimed, (see PEACH, 1916 p. 297) and since his levels seem to agree fairly well with those they record in the Sassen area, the evidence tends to contradict the suggestions of WORDIE (1921) and BALCHIN (1941) that warped shorelines exist in Vestspitsbergen. This does not seem to the writer to be necessarily the case: BALCHIN emphasised that the tilted shorelines which he mapped in Sassenfjorden and Billefjorden were essentially local readjustements to isostatic pressure. The idea of eustatic changes of sea-level postulated by HORN and

Orvin (1918) is not necessarily excluded. (This idea has been tentatively discussed elsewhere by the present author. Dineley, 1953, p. 507). The recognition of faunal horizons and limits along the lines initiated by Feyling-Hanssen and Jørstad should be attempted over wide areas before the problem of warped shorelines and eustatic recovery or changes of level can be considered in anything but a local sense.

The observations recorded above, while not on a comparable scale with those published for the Sassen area, do give some measure of support for the scheme of zones outlined by Feyling-Hanssen and Jørstad. In the present area the following table may be said to apply.

3. *Saxicava-Mya* horizon	21—30 m.
3. *Saxicava-Mya-Astarte* horizon	10—21 m.
1. *Mytilus* horizon	up to 12 m.

There does not seem to be sufficient evidence to distinguish an upper and a lower *Astarte* horizon, though a *Mya* division from 10 m. to 30 m. is possible.

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NORSK GEOLOGISK TIDSSKRIFT 34

SILURIAN OSTRACODS FROM THE OSLO REGION, NORWAY

1. Beyrichiacea. With a revision of the Beyrichiidae.

BY

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Abstract. The family Beyrichiidae is discussed and divided into 4 subfamilies; Beyrichiinae, Kloedeniinae, Zygobolbinae, and Treposellinae subfam.n. A new genus, *Cornikloedenia*, and 5 new subgenera of *Beyrichia* (*Eobeyrichia*, *Neobeyrichia*, *Nodibeyrichia*, *Velibeyrichia*, and *Mitrobeyrichia*) are erected. 26 beyrichiacean ostracods from the Silurian of the Oslo region are described. A chart (p. 67) shows their stratigraphical and geographical distribution. The genus *Signetopsis* is new, and the following species and subspecies are also new: *Beyrichia paucituberculata*, *B. zygophora*, *B. osloensis*, *B. skienensis*, *B. kiaeri*, *B. ringerikensis*, *Craspedobolbina armata*, *C. dorsoplicata*, *C. expansinodata*, *Platybolbina tiara densistriata*, *P. lunulifera*, *P.? bulbosa*, *Primitiella? bipunctata*, *Primitiopsis dorsoplicata*, *Signetopsis quadrilobata*, and *S. malornata*.

Introduction and acknowledgements

Ostracods from the Silurian of the Oslo region were first reported by KJERULF (1865), who listed *Leperditia baltica*, *L. phaseolus*, and *Beyrichia* spp. in his «Veiviser ved Geologiske Excursioner i Christiania Omegn».

KIÆR, in his classical monograph «Das Obersilur im Kristianiagebiete» (1906), described a new *Leperditia* species, *L. norvegica*, from 9g in Ringerike, and reported several other *Leperditia* species, *Primitia* spp. (apparently mainly species which are assigned here to *Craspedobolbina*, *Platybolbina*, and *Apatobolbina*), *Beyrichia* spp., and *Beyrichia* cf. *Klödeni* from various horizons. Further he listed *Beyrichia* cf. *tuberculata* from 9g in Ringerike (apparently *B. ringerikensis* sp. n.).

The present paper deals with the Silurian Beyrichiacea of the Oslo region, and is based on material preserved in the Paleontological Museum of the University of Oslo. In a later paper the writer hopes to be able to describe the Leperditiacea.

The writer wishes to thank his friend cand. real. N. SPJELDNÆS for helpful suggestions during the preparation of this paper, and Faculty Photographer, Miss B. MAURITZ for the tedious task of taking the photographs of the ostracods.

Furthermore, the writer wishes to express his gratitude to Miss GERALDINE ROCH, National Museum of Ireland, for making available to him type material of *Beyrichia kloedeni* McCOY.

REVISION OF THE FAMILY BEYRICHIIDAE

Terminology

Text fig. 1.

The terminology used is that proposed by KESLING (1951a) with a few amendments given by HENNINGSMOEN (1953a). A few additional terms are introduced below.

The orientation of the valve is believed to be as shown in text figure 1. The median lobe will then be situated in front of the median sulcus, and the larger of the two other lobes will be the posterior lobe. The brood-pouch will consequently occupy an antero-ventral position. The writer's reasons for using this orientation has been explained earlier (HENNINGSMOEN, 1953a, p. 196).

HESSLAND (1949, pp. 139—140) introduced the symbols S1, S2, and S3 for the three sulci, and L1, L2, L3, L4 for the four lobes of the quadrilobate ostracods, S1 and L1 being the anterior sulcus and anterior lobe, respectively. In the trilobate Beyrichiidae (and other trilobate Beyrichiacea) the anterior and median sulcus may be assumed to correspond to S1 and S2, and the anterior and median lobe to L1 and L2. The posterior lobe may be given the symbol *Lp*. It appears probable that it corresponds to L3 + L4 in quadrilobate ostracods. In the quadrilobate *Drepanellina* of the Kloedeniinae, L3 and L4 appear to correspond to Lp in closely related genera. The genus *Mastigobolbina* of the Zygobolbinae is usually trilobate as *Beyrichia*, but in one species, *M. bifida* ULRICH & BASSLER 1923, there is a distinct S3 which splits the posterior lobe into two lobes. The anterior and posterior lobe of *Beyrichia* are often provided with dorsal projections («horns»). The anterior lobe carries only one horn (*anterior horn*), whereas the posterior lobe often has two (*inner* and *outer posterior horn*). It seems reasonable to believe that the two posterior horns indicate that the posterior lobe represents two fused lobes, the horns being their dorsal ends.

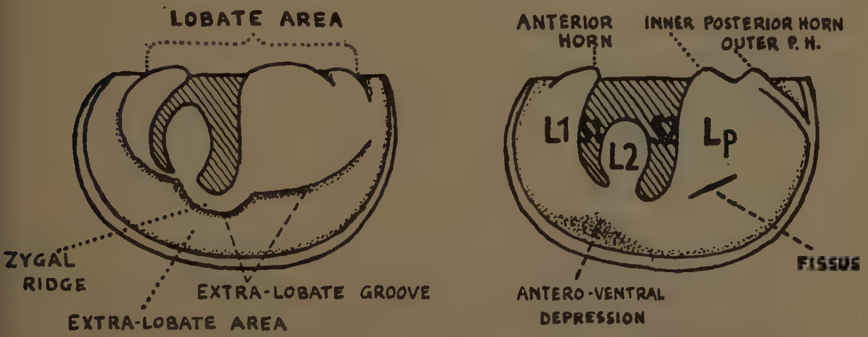

Fig. 1. Some terms used in the description of Beyrichiidae.

A characteristic feature of many *Beyrichia* species is a faint groove (here referred to as the *fissus*) developed across the posterior lobe. It is apparently a remainder of the *extra-lobate groove* in early *Beyrichia* species (subgenus *Eobeyrichia*). The fissus in *Beyrichia* is often rather faint, but it is accentuated in tuberculate species by not being tuberculate. Futhermore the near-by tubercles are often arranged parallel to the fissus. This may explain the development of a secondary fissus, dorsal to the usual one in some advanced forms, as *B. tuberculata* (Klöden 1834). Especially in pouch-bearing valves, one or both of the edges of the fissus may be swollen so as to form lip-like ridges, which may be more prominent than the fissus itself.

Just as the sulci and lobes may be correlated with those of genera like *Tallinnella*, the submarginal ridge (or frill) may be correlated with the velate structure of Ordovician Paleocopa. (The velate ridge in *Beyrichia* was referred to as the carinal ridge by Spjeldnæs, 1952. For the discrimination of the velate and carinal structures see Henningsmoen, 1953a, p. 190).

Another characteristic feature which may be developed in pouchless valves of *Beyrichia* is the *antero-ventral depression*, situated between the velate structure and the fusion point of L1 and the L2—Lp complex. Its position corresponds to a point inside the centre of the brood pouch in pouch-bearing valves.

A short *postero-dorsal ridge* is often developed. A more or less

U-shaped ridge may be developed around the ventral end of the sulcus, uniting L2 and Lp. It may continue up along the anterior border of Lp, as is usual in the Zygobolbinae. It is referred to here as the *zygal ridge* (Gr. *Ζυγον* = yoke).

Classification of the Beyrichiidae

Family Beyrichiidae Jones 1894.

Diagnosis: — Dimorphic Beyrichiacea, where one of the dimorphs of each species has a pouch. Non- to trisulcate. S1 more persistent than S3. Velate structure usually present as a ridge or frill.

Remarks: — As defined above, this family includes the four closely related subfamilies Beyrichiinae, Kloedeniinae, Zygobolbinae, and Treposellinae subfam.n.

Subfamily Beyrichiinae Jones 1894.

Diagnosis: — As for family. The pouch has a more or less anteroventral position. S1 (when present) shorter than S2. Zygal ridge usually lacking; when present its posterior branch does not reach the dorsal border. Velate structure developed as a tuberculate, spinose or smooth ridge, or as a frill, or it may (very rarely) not be developed at all.

Remarks: — The subfamily now differs from it as defined by Henningsmoen (1953a, p. 238) in that the subfamily Kloedeniinae has been split off. Furthermore, *Craspedobolbina*, which was tentatively included in the Zygobolbinae by Henningsmoen (1953a, p. 239), is included in the Beyrichiinae (cf. below), and *Treposella*, *Bolbiprimitia*, and *Mesomphalus* are transferred to the new subfamily Treposellinae. The relationships of *Bolbibollia*, *Apatobolbina*, and *Dibolbina* to the other beyrichiids are uncertain, but for the time being they may be assigned to the Beyrichiinae. *Apatobolbina* and *Dibolbina* have a well-developed frill, and are probably closer to the Beyrichiinae than to the Kloedeniinae, as no frill-bearing forms are known in the Kloedeniinae.

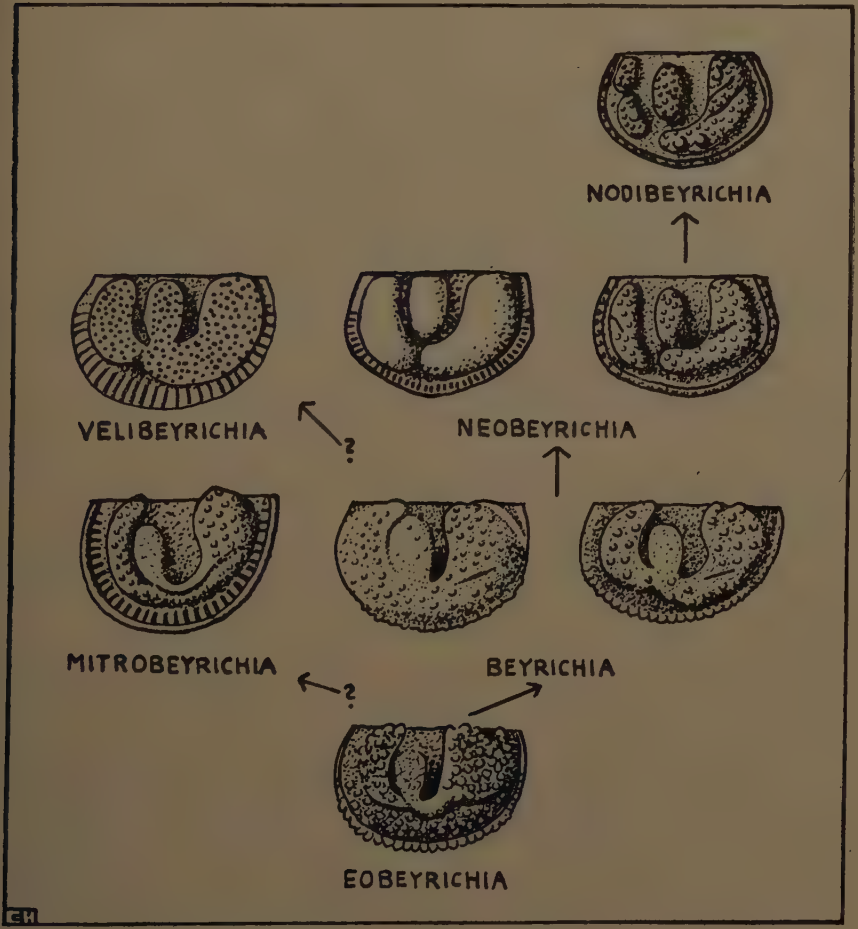

Fig. 2. Possible relationships between the subgenera of *Beyrichia*.

Genus *Beyrichia* McCoy 1846.

Text fig. 2.

Type species: — *Beyrichia kloedeni* McCoy 1846. Swartz (1936, p. 586) maintains that *B. tuberculata* (Klöden 1834) must be regarded as the type species, as it appears as if McCoy (1846) believed that *B. tuberculata* and *B. kloedeni* were synonyms. This may not have been what McCoy meant, because in 1851 (p. 135) he rather strongly emphasized that the two species are not synonymous. It appears therefore that *B. kloedeni* may still be regarded as the type species.

Remarks: — Many species which were earlier assigned to *Beyrichia* do not show the beyrichiid type of dimorphism, and have been removed (or should be removed) from this genus. Nevertheless,quite a large number of species belong to *Beyrichia*. As different trends may be distinguished, it is proposed to divide *Beyrichia* into the following subgenera: *Beyrichia*, *Eobeyrichia* subgen.n., *Neobeyrichia* subgen.n., *Nodibeyrichia* subgen.n., *Velibeyrichia* subgen.n., and *Mitrobeyrichia* subgen.n.

Subgenus *Eobeyrichia* subgen.n.

Name: — The name *Eobeyrichia* alludes to the early appearance of this genus.

Type species: — *Beyrichia* (*Eobeyrichia*) *zygophora* sp.n.

Diagnosis: — *Beyrichia* species with zygal ridge uniting L2 and Lp, with extra-lobate groove, and with tuberculate (spinose?) velate ridge.

Remarks: — Four early *Beyrichia* species, desribed below as *B.* (*E.*) *paucituberculata*, *B.* (*E.*) *zygophora*, *B.* (*E.*) *osloensis*, and *B.* (*E.*) *skienensis*, are assigned to this subgenus. As far as the writer knows, no earlier described *Beyrichia* species seem to belong to it. The extra-lobate groove is especially characteristic, whereas a zygal ridge is developed also in *Mitrobeyrichia*, which, however, has a velate frill. It is probable that the subgenus *Beyrichia* developed from the subgenus *Eobeyrichia* through forms like *B.* (*E.*) *skienensis* sp.n. It is possible that the subgenus *Mitrobeyrichia* developed from *Eobeyrichia*. The subgenus *Eobeyrichia* is of special interest as it appears to be closely related to early zygobolbids and to the type species of *Craspedobolbina*.

Occurrence: — Llandoverian of Norway.

Subgenus *Beyrichia* McCoy 1846.

Type species: — *Beyrichia kloedeni* McCoy 1846.

Diagnosis: — *Beyrichia* species with the three lobes joined ventrally, although an antero-ventral depression may be present. A fissus is usually seen. Velate structure developed as a smooth, nodular, or spinose ridge. Surface finely granulose with scattered coarser granules (or spines), but the surface ornamentation may be more or less effaced.

Remarks: — *Beyrichia kloedeni* (redescribed by SHAW, 1928) is based on internal moulds. As discussed below, internal moulds do not show the fissus. Thanks to the kindness of Miss Geraldine Roch, National Museum of Ireland, the writer has had the opportunity to examine McCOY's type material from the sandstones at Boocaun, Cong, County Galway. A few external impressions show a faint fissus, in spite of the preservation in sandstone. The sand grains are too coarse to permit one to recognize the original surface ornamentation. It may be added that the external impressions show that *B. kloedeni* had a granulose velate ridge. The impressions are seen on the slab which contains the internal mould figured by SHAW (1928, pl. 1,fig. 1).

The forms included in the subgenus *Beyrichia* may either be rather tumid as *B. kloedeni* and *B. umbonata*, where the lobes are confluent with the extra-lobate area and form a rather evenly convex area (except for the sulci), or they may have more slender lobes, separated from a less convex extra-lobate area, as in *B. kloedeni bicuspis*. In the latter case an antero-ventral depression is usually present. Transitional forms between these two forms occur, and the writer believes that a variation from the one form to the other may occur within one species (see description of *B.* cf. *kloedeni*).

Many names have been given to forms of the subgenus *Beyrichia*, such as:

Beyrichia kloedeni McCOY 1846.
B. protuberans BOLL 1862 (see also KIESOW, 1888).
B. nodulosa BOLL 1862 (see also KIESOW, 1888).
B. spinigera BOOL 1862 (see also KRAUSE, 1891).
B. verrucosa KOLMODIN 1869.
B. bolliana umbonata REUTER 1885.
B. kloedeni var. *tuberculata* SALTER[1] subvar. *clausa* JONES & HOLL 1886.

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[1] SALTER never erected any species or variety *tuberculata*, but assigned some specimens to KLÖDEN's species *tuberculata* (originally *Battus tuberculata*) in 1839. In any case, a *Beyrichia tuberculata* SALTER 1839 would be a younger homonym of *B. tuberculata* (KLÖDEN, 1834) and thus not be available.

B. kloedeni var. *scotica* JONES & HOLL 1886.
B. kloedeni var. *bicuspis* KIESOW 1888.
Kloedenia obesa HARPER 1940.

Kloedenia salopiensis HARPER 1940 probably also belongs here, although its velate spines are more or less fused to form a frill.

The specimen figured by JONES & HOLL (1886, pl. XII, fig. 8) as *Beyrichia kloedeni* var. *tuberculata* SALTER probably belongs to the subgenus *Beyrichia.*

Affinities: — It seems rather likely that the subgenus *Beyrichia* developed from the subgenus *Eobeyrichia,* in which case the fissus in *Beyrichia* appears to be a remnant of the extra-lobate groove in *Eobeyrichia. Beyrichia* (*Beyrichia*) *kiaeri* sp.n. appears to be transitional between the subgenera *Beyrichia* and *Neobeyrichia,* and might perhaps equally well have been assigned to the latter.

Occurrence: — *Beyrichia* (*Beyrichia*) occurs in the Upper Llandoverian, Wenlockian, and Ludlovian of Europe, but no described North American species appear to belong to this subgenus.

Subgenus *Velibeyrichia* subgen.n.

Name: — The name *Velibeyrichia* alludes to the usually well-developed frill (velum) of this subgenus.

Type species: — *Beyrichia moodeyi* ULRICH & BASSLER 1908.

Diagnosis: — *Beyrichia* species with the three lobes more or less well united ventrally. Velate structure developed as a frill, usually rather wide. No fissus is present. Surface reticulate or pitted, but the ornamentation may be effaced.

Remarks: — The following species are probably closely related and may be included in this subgenus:

Beyrichia granulosa HALL 1877 (cf. ULRICH & BASSLER, 1923, p. 655).
B. moodeyi ULRICH & BASSLER 1908.
B. waldronensis ULRICH & BASSLER 1908.
B. mesleri ULRICH & BASSLER 1923.
B. veronica ULRICH & BASSLER 1923.
B. tonolowayensis ULRICH & BASSLER 1923.
B. normalis ULRICH & BASSLER 1923.

B. hartnageli ULRICH & BASSLER 1923
and probably also the Lower Devonian *B. fittsi* ROTH 1929.

Affinities: — This subgenus may be rather close to the subgenus *Beyrichia*, but differs in usually having a wide frill, in never having any fissus, and in having a reticulate or pitted ornamentation where a surface ornamentation is developed.

Occurrence: — Upper Clinton, Niagaran (Waldron), and McKenzie formations and? Devonian Haranger Marl of North America. This subgenus does not seem to be known from Europe.

Subgenus *Neobeyrichia* subgen. n.

Name: — The name *Neobeyrichia* alludes to the rather late appearance of this subgenus.

Type species: — *Beyrichia buchiana* JONES 1855.

Diagnosis: — *Beyrichia* species with L1 isolated from L2 and Lp. L2 and Lp may be united or not. Velate structure developed as a ridge, or a narrow ridge-like frill. Surface granulose or smooth.

Remarks: — This subgenus includes forms with rather tumid lobes as *B. salteriana* and forms with slender lobes as *B. buchiana*. The following forms appear to belong here:

Beyrichia buchiana JONES 1855.
B. antiquata JONES 1855.
B. salteriana JONES 1855.
B. kochii BOLL 1862.
B. buchiana incisa REUTER 1885.
B. buchiana angustata REUTER 1885.
B. buchiana REUTER 1885[1].
B. maccoyiana sulcata REUTER 1885.
B. maccoyiana lata REUTER 1885[1].
B. lauensis KIESOW 1888.
B. lindströmi KIESOW 1888.
B. lindströmi expansa KIESOW 1888.
B. reuteri KRAUSE 1891.
B. borussica KIESOW 1892.
B. borussica protuberans KIESOW 1892.

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[1] Preoccupied by *Beyrichia lata* HALL 1852.

and possibly also *B. maccoyiana* Jones 1855 and *B. dubia* Reuter 1885. The Devonian species *B. latispinosa* Přibyl 1951 should probably be included in this subgenus.

Affinities: — This subgenus probably developed from the subgenus *Beyrichia* through forms like *B.* (*B.*) *kiaeri* sp.n. The subgenus *Nodibeyrichia* no doubt developed from *Neobeyrichia*.

Occurrence: — Upper Ludlovian, Downtonian and Devonian of Europe.

Subgenus *Nodibeyrichia* subgen. n.

Name: — The name *Nodibeyrichia* alludes to the tendency of the lobes to split into nodes.

Type species: — *Beyrichia bronni* Reuter 1885.

Diagnosis: — *Beyrichia* species with L1 split into two nodes. Lp may also be split into two or more nodes. A secondary fissus may be present. Velate structure developed as a ridge. Surface granulose or smooth.

Remarks: — This subgenus of advanced *Beyrichia* species embraces a number of forms, such as:

Beyrichia tuberculata Klöden 1834.
B. tuberculata var. *nuda* Jones 1855.
B. tuberculata var. *torosa* Jones 1855.
B. pustulosa Hall 1860.
B. gedanensis Kiesow 1884.
B. tuberculata gibbosa Reuter 1885.
B. tuberculata bigibbosa Reuter 1885.
B. «tuberculato-buchiana» Reuter 1885.
B. «tuberculato-kochiana» Reuter 1885.
B. noetlingi Reuter 1885.
B. noetlingi conjuncta Reuter 1885.
B. bronni Reuter 1885.
B. baueri Reuter 1885.
B. baueri tripartita Reuter 1885.
B. «buchiano-tuberculata» Reuter 1885.
B. tuberculata var. *strictispiralis* Jones 1891.

Affinities: — This subgenus probably developed from the subgenus

Neobeyrichia through forms like *B.* (*Neobeyrichia*) *buchiana.*

Occurrence: — Uppermost Ludlovian and Downtonian of Europe, and Arisaig of Nova Scotia.

Subgenus *Mitrobeyrichia* subgen.n.

Name: The name *Mitrobeyrichia* alludes to the girdle-like frill of this species (Gr. *μιτρα* = girdle).

Type species: — *Beyrichia jonesii* BOLL 1856.

Diagnosis: — *Beyrichia* species with L2 and Lp united by a zygal ridge. A groove is developed below this ridge. Velate structure developed as a narrow frill with a thickened margin.

Remarks: — The frill is especially characteristic of this subgenus, which includes at least the following forms:

Beyrichia jonesii BOLL 1856.

B. hians BOLL 1856.

B. scanensis KOLMODIN 1819.

B. clavata KOLMODIN 1869 (subj. syn. of *jonesii*, cf. SPJELDNÆS, 1951).

B. lakemontensis ULRICH & BASSLER 1923

and possibly also *B. kirki* ULRICH & BASSLER 1923 and *Bollia interrupta* JONES 1887.

Affinities: — This subgenus, with a zygal ridge, may have developed directly from *Eobeyrichia*, which likewise has a zygal ridge, but no velate frill.

Occurrence: — Upper Valentian (cf. HARPER, 1940) to Downtonian of Europe. Upper Clinton of North America.

Genus *Craspedobolbina* KUMMEROW 1924.

Type species: — By original designation, *Craspedobolbina dietrichi* KUMMEROW 1924. SCHMIDT (1941, p. 27) has examined the type material of this species and of *Primitia schmidtii* KRAUSE 1889 and believes that they are synonyms. No pouchbearing individuals of *Primitia schmidtii* have been reported, and as the associated fauna of this species suggests a Middle Ordovician age, whereas *Craspedobolbina dietrichi* probably comes from near the Ordovician-Silurian boundary, it may be safest to retain the name *dietrichi* for the type species.

Remarks: — The stratigraphic position of the type species is uncertain as it comes from a drift boulder in northern Germany. It probably comes from near the Ordovician-Silurian border, probably from the Upper Ordovician as suggested by KUMMEROW. Some Silurian species described below appear to be related to the type species of *Craspedobolbina*, and are included in this genus. Especially the earliest of these, the Llandoverian *C. armata* sp.n. seems to be close to *C. dietrichi.*

Craspedobolbina was tentatively included in the Zygobolbinae by HENNINGSMOEN (1953a) but is transferred here to the Beyrichiinae, as it does not posses the typical U-ridge of the early Zygobolbinae, but only a short zygal ridge, which is also present in an early new subgenus (*Eobeyrichia*) of *Beyrichia*. *C. dietrichi* may be rather close to *Eobeyrichia*, but it is probably also related to the Zygobolbinae.

If the four new species described below are included in *Craspedobolbina*, the following diagnosis may be given of this genus:

Diagnosis: — Unisulcate to nonsulcate beyrichiids with an anteroventral pouch, which may be more or less distinctly separated from the rest of the valve. Velate structure developed as a frill in pouchless valves and as a ridge in pouchbearing valves, or as a ridge in both types, or it may be lacking. When a median lobe (L2) can be distinguished, it does not reach the dorsal border. Surface granulose, reticulate, or smooth.

Genus *Apatobolbina* ULRICH & BASSLER 1923.

Type species: — *Apatobolbina granifera* ULRICH & BASSLER 1923, by original designation.

Remarks: — *Apatobolbina* was tentatively included in the Beyrichiidae by HENNINGSMOEN (1953a, pp. 227, 238), as the pouch appeared to be of the beyrichiid type (i. e. it opens into the main cavity of the carapace). Material described below has verified this for *A. platygaster* KUMMEROW 1924. As discussed by HENNINGSMOEN (1953a, p. 227) some species with short sulcus or sulcal pit (earlier assigned to *Chilobolbina*) should probably be included in this genus. *A. platygaster* occurs through all of the Wenlock series in Norway, whereas the North American species occur in the Lower to Upper Clinton formation.

Genus *Dibolbina* ULRICH & BASSLER 1923.

Type species: — *Dibolbina cristata* ULRICH & BASSLER 1923, by original designation.

Remarks: — This genus was erected for the two species *D. cristata* and *D. producta* ULRICH & BASSLER 1923, both from the Tonoloway formation. It is possible that *Beyrichia steusloffi* KRAUSE 1891 from the Downtonian of Europe should also be included in this genus, in spite of it being bisulcate.

Genus *Bolbibollia* ULRICH & BASSLER 1923.

Type species: — *Bolbibollia labrosa* ULRICH & BASSLER 1923, by original designation.

Remarks: — The type species and only known species comes from the Anticostian formation of the Island of Anticosta.

Subfamily Kloedeniinae ULRICH & BASSLER 1923.

Diagnosis: — As for family, but the velate structure is always a smooth ridge. Surface usually smooth, but may be pitted. The pouch is usually not well defined, and has a more or less anteroventral position. Only bi- and trisulcate forms are known, but S1 may be very faint in some bisulcate species.

Remarks: — This subfamily was originally erected as a subfamily of the Zygobolbidae. However, ULRICH & BASSLER (1923) also included *Mastigobolbina* and *Plethobolbina* in the Kloedeniinae (these were transferred to the Zygobolbinae by HENNINGSMOEN, 1953a, p. 236) and *Steusloffia* (which is not a pouch-bearing genus, and has been removed from the Beyrichiidae). The remaining genera of the Kloedeniinae were included in the Beyrichiinae by HENNINGSMOEN(1953a). The subgenus Kloedeniinae is revived here for a group of closely related genera, namely *Kloedenia*, *Welleria*, *Kyammodes*, *Drepanellina*, *Cornikloedenia* gen. n., and *Zygobeyrichia*. These genera are no doubt closer to *Beyrichia* than to the Zygobolbinae, as they for instance have no zygal ridge.

Genus *Kloedenia* JONES and HOLL 1886.

Type species: — *Beyrichia wilckensiana* JONES 1855, designated by ULRICH & BASSLER, 1908.

Remarks: — It has become the practice to regard *Kloedenia normalis* ULRICH & BASSLER 1923 as a typical member of this genus. The type species, however, differs from *K. normalis* and allied species in having a comparatively wide area between the posterior lobe and the posterior margin. It is possible that the posterior lobe corresponds to L3 and that the area behind it corresponds to L4. Some other species agree with the type species in this feature, as for instance *K. kiesowi* KRAUSE 1891 (transferred to *Kyammodes* by KUMMEROW, 1933). Perhaps it may be better later on to restrict *Kloedenia* to the species agreeing with *K. wilckensiana* in this respect, and assign *K. normalis* and allied species to a new subgenus or genus, or possibly to *Welleria* (cf. below). For the present one may divide the *Kloedenia* species into two groups; the group of *K. wilckensiana* and the group of *K. normalis.*

Group of Kloedenia wilckensiana. The North American species *Kyammodes swartzi* ULRICH & BASSLER 1923 is very close to *Kloedenia kiesowi*, and should be included in this group (cf. under *Kyammodes*). The American species occurs in the Lower Tonoloway formation, whereas the European species of this group occur in the Downtonian.

Group of Kloedenia normalis. Typical members of this group are *K. normalis*, *K. normalis depressa*, *K. cacaponensis*, *K. kenziensis*, and *K. longula* (all erected by ULRICH & BASSLER 1923). They are distributed from the Upper Clinton to the Will's Creek formation. Several Devonian species, as *K. manliensis* WELLER 1903, seem to agree rather well with this group. As discussed below, *Welleria* may be close to this group. *Kyammodes tricornia* appears to be closer to this group than to the type species of *Kyammodes* (cf. below).

There has been some confusion between *Beyrichia* and *Kloedenia*, probably because smooth *Beyrichia* species and especially internal moulds of *Beyrichia* resemble members of the *Kloedenia normalis* group. However, the median lobe in *Kloedenia* usually reaches or projects above the hinge line, whereas this is not so commen in *Beyrichia.* Furthermore the pouch is usually better defined in *Beyrichia* than in *Kloedenia.* HARPER (1940) describes two species as *Kloedenia* *obesa* and *K. salopiensis*. However, both are rather typical *Beyrichia* species, showing the ordinary *Beyrichia*-granulation and even the characteristic fissus, not known in *Kloedenia* or allied species. SWARTZ (1936, p. 586) fears that *Beyrichia kloedeni* is congeneric with the *Kloedenia* species. However, it shows the usual *Beyrichia* lobation, although the species is based on an internal mould, and accordingly does not show the fissus (cf. p. 23).

It may be added that some Ordovician species which have been assigned to *Kloedenia* probably are not closely related to this genus. *Kloedenia globifera* (KRAUSE 1892), for instance, belongs to the genus *Hesperidella* ÖPIK 1937.

Genus *Welleria* ULRICH & BASSLER 1923.

Type species: — *Welleria obliqua* ULRICH & BASSLER 1923, by original designation.

Remarks: — The three North American forms *W. obliqua*, *W. obliqua brevis*, and *W. obliqua longula* are very closely related, and may represent individual variations within one species. They are all from the Lower Tonoloway formation, whereas *W. aftonensis* WARTHIN 1934 comes from the Devonian Traverse formation. *W. primitioides* KUMMEROW 1924 appears to be closer to *Kyammodes*. *Welleria* differs from *Kloedenia* in having a less well-defined pouch, but appears to be very close to the group of *Kloedenia normalis*, perhaps even closer than is the group of *Kloedenia wilckensiana*.

Genus *Cornikloedenia* gen.n.

Text fig. 3.

Name: — The name *Cornikloedenia* alludes to the ventral horn or node of this *Kloedenia*-like genus.

Type species: — *Drepanellina ventralis* ULRICH & BASSLER 1923.

Diagnosis: — A *Kloedenia*-like beyrichiid with a ventral node or short ridge well below S2. Bi- or trisulcate.

Remarks: — The three species *Drepanellina ventralis*, *D. claypolei*, and *Zygobeyrichia ventricornis* (all ULRICH & BASSLER 1932) seem to be rather closely related. As they do not seem to fit in easily with either *Drepanellina* or *Zygobeyrichia*, they are assigned to a new genus; *Cornikloedenia*. ULRICH & BASSLER (1923) hesitatingly assigned *ventralis* to *Drepanellina*, whereas *D. claypolei* was regarded as intermediate between *D. ventralis* and the typical *Drepanellina* species. Even if *Cornikloedenia claypolei* is trisulcate, it is not certain that it is very close to *Drepanellina*. It is possible that *Zygobeyrichia* developed from *Cornikloedenia*, but it is also possible that it developed from *Kloedenia*. *Cornikloedenia* is at present known from the Upper Clinton formation and the Will's Creek formation.

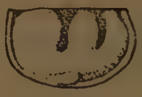

Fig. 3. *Cornikloedenia ventralis* (ULRICH & BASSLER 1923). x 10. Redrawn after ULRICH & BASSLER, 1932, pl. LVI, fig. 5.

Genus *Kyammodes* JONES 1888.

Type species:—The Devonian *Kyammodes whidbornei* JONES 1888, by original designation.

Remarks: — Rather characteristic of the type species is the very small and short median lobe, and the great overlap along the ventral border. Some species assigned to *Kyammodes*, like *K. kiesowi* (KRAUSE 1891), *K. swartzi* ULRICK & BASSLER 1923, and *K. tricornia* ULRICH & BASSLER 1923, do not agree with the type species in these features, and should rather be included in *Kloedenia*. Also *Beyrichia notata* HALL 1861 (transferred to *Kyammodes* by BASSLER & KELLETT, 1934) appears to belong to the group of *Kloedenia normalis*. The Ordovician *Kloedenia? globosa* KRAUSE 1889 (transferred to *Kyammodes* by BASSLER & KELLETT, 1934) is probably not a beyrichiid, and should be removed from *Kyammodes*. On the other hand it is probable that *Welleria primitioides* KUMMEROW 1934 should be included in *Kyammodes*.

Genus *Drepanellina* ULRICH & BASSLER 1923.

Type species: — *Drepanellina clarkei* ULRICH & BASSLER 1923, by original designation.

Remarks: — As discussed above, *D. claypolei* and *D. ventralis* have been transferred to the new genus *Cornikloedenia*. This leaves a rather well-defined group of Upper Clinton species in *Drepanellina*.

The Devonian *D? laquens* MATERN 1929 is probably not a beyrichiid, and should be removed from *Drepanellina.* The likewise Devonian *Drepanellina bohemica* PŘIBYL 1951 is probably not congeneric with *D. clarkei.*

Genus *Zygobeyrichia* ULRICH 1916.

Type species: — *Zygobeyrichia apicalis* ULRICH 1916, by original designation.

Remarks: — After *Z. ventralis* has been transferred to the new genus *Cornikloedenia, Zygobeyrichia* appears to be a rather well-defined group, known from the Will's Creek and Tonoloway formations, and from the Devonian of North American .

Subfamily Treposellinae subfam. nov.

Type genus: — *Treposella* ULRICH and BASSLER 1923.

Diagnosis: — Beyrichiids with a mainly ventrally situated pouch. Only uni- and nonsulcate forms are known.

Included genera: —

Treposella ULRICH & BASSLER 1913 (type: *Beyrichia lyoni* ULRICH 1891).

Bolbiprimitia KAY 1940 (type: *Halliella fissurella* ULRICH & BASSLER 1923).

Hibbardia KESLING 1953b (type: *Amphissites lacrimosus* SWARTZ & ORIEL 1948).

Phlyctiscapha KESLING 1953a (type: *P. rockportensis* KESLING 1953a).

?Mesomphalus ULRICH & BASSLER 1913 (type: *M. hartleyi* ULRICH & BASSLER 1913).

Remarks: — These North American genera are all rather late; *Bolbiprimitia* comes from the upper part of the Tonoloway formation, and the others from the Devonian. Their general aspect is rather varied, and they are uni- or non-sulcate. However, they all have a rather ventrally situated pouch, and this feature distinguishes them from all the other beyrichiids, where the pouch occupies an antero-ventral or anterior position.

Hibbardia is apparently rather close to *Bolbiprimitia*, the main difference being that *Hibbardia* has a shallow sulcus with a deep sulcal pit, whereas *Bolbiprimitia* has a well developed sulcus. *Hibbardia* is also closely related to *Treposella* (cf. KESLING 1953b, p. 20) and to *Phlyctiscapha* (cf. KESLING, 1953a, p. 222). The position of *Mesomphalus* is less certain. However, it agrees with the others in having a rather ventrally situated pouch.

It is possible that the Treposellinae developed from *Craspedobolbina*, as some Silurian species assigned here to this genus resemble some of the Treposellinae, except in having a more anterior position of the pouch. These late *Craspedobolbina* species agree with most of the Treposellinae in having the pouch rather confluent with the rest of the valve (at least exteriorly).

Hibbardia resembles *Amphissites*, and it is not improbable that the Kirkbyidae developed from the Beyrichiidae through forms like *Hibbardia* by the loss of the pouch.

Subfamily Zygobolbinae ULRICH & BASSLER 1923.

Diagnosis: — As for family. The pouch has an anterior or anteroventral position. S1 (when present) longer than S2. A zygal ridge is usually present; its posterior branch reaches the dorsal border.

Remarks: — This subfamily (as defined by HENNINGSMOEN, 1953a, p. 238) includes the following genera: *Zygobolba*, *Zygobolbina*, *Zygosella*, *Mastigobolbina*, *Plethobolbina*, and *Bonnemaia* (all ULRICH & BASSLER 1923). They all come from the Clinton formation, and do not seem to be known outside of North America. The genus *Craspedobolbina* was tentatively assigned to this subfamily by HENNINGSMOEN (1953a). Additional material, described below, seems to indicate that it should rather be included in the Beyrichiinae. Nevertheless, the Zygobolbinae and *Craspedobolbina* may have had a common origin.

Origin and trends of the Beyrichiidae.

(Text fig. 4.)

It is generally assumed that the beyrichiids developed from the eurychilinids. This appears to be rather probable, as early beyrichiids have much in common with species of *Platybolbina*. A species described below as *Platybolbina? bolbosa* sp.n. resembles both the eurychilinids and the beyrichiids. It is assigned to a eurychilinid genus, because no pouch-bearing valves were found. If more material should show later on that this species did include specimens with pouch, it would fit well into the Beyrichiidae. It is the pouch, opening into the main cavity of the valve, which distinguishes the Beyrichiidae from the other paleocop families.

A chart (p. 36) illustrates the vertical distribution of the beyrichiids, and also distinguishes between the European and North American members (very few beyrichiids have been described from other areas). The chart is not presented to give a correlation between North American and European strata. The correlation may as yet be uncertain. The ranges of the European members should be compared with the European time scale, and those of the North American members with the North American time scale. The writer has mainly taken into consideration species whose stratigraphic position is known. No doubt a better knowledge of the beyrichiids will change this chart, but it may already show some main trends within the Beyrichiidae. The finely dotted lines indicate possible relationships, but should not be interpreted as showing exactly when a group branched off from another group.

The genera of the Kloedeniinae are all closely related. Early species of the *Kloedenia normalis* group appear to be rather close to *Beyrichia*, and it is possible that the Kloedeniinae developed from *Beyrichia*. The subfamily Zygobolbinae constitutes a well defined unit of closely related beyrichiids. Early Zygobolbinae and early Beyrichiinae (*Craspedobolbina* and *Beyrichia* species) agree in so many features (e. g. in having a zygal ridge) that their origin is most probably monophyletic. If the type species of *Craspedobolbina* comes from Upper Ordovician beds, it is probably the earliest known beyrichiid. Several other Ordovician species have been assigned to beyrichiid genera, but probably none of them belong to the Beyrichiidae. At least those which have been restudied have not been shown to develop a beyrichiid pouch. It is possible that the Beyrichiidae arose about the Upper Ordovician time. The relationship of the rather early genus *Apatobolbina* to the other beyrichiids is uncertain, and one should not exclude the possibility of a polyphyletic origin of the

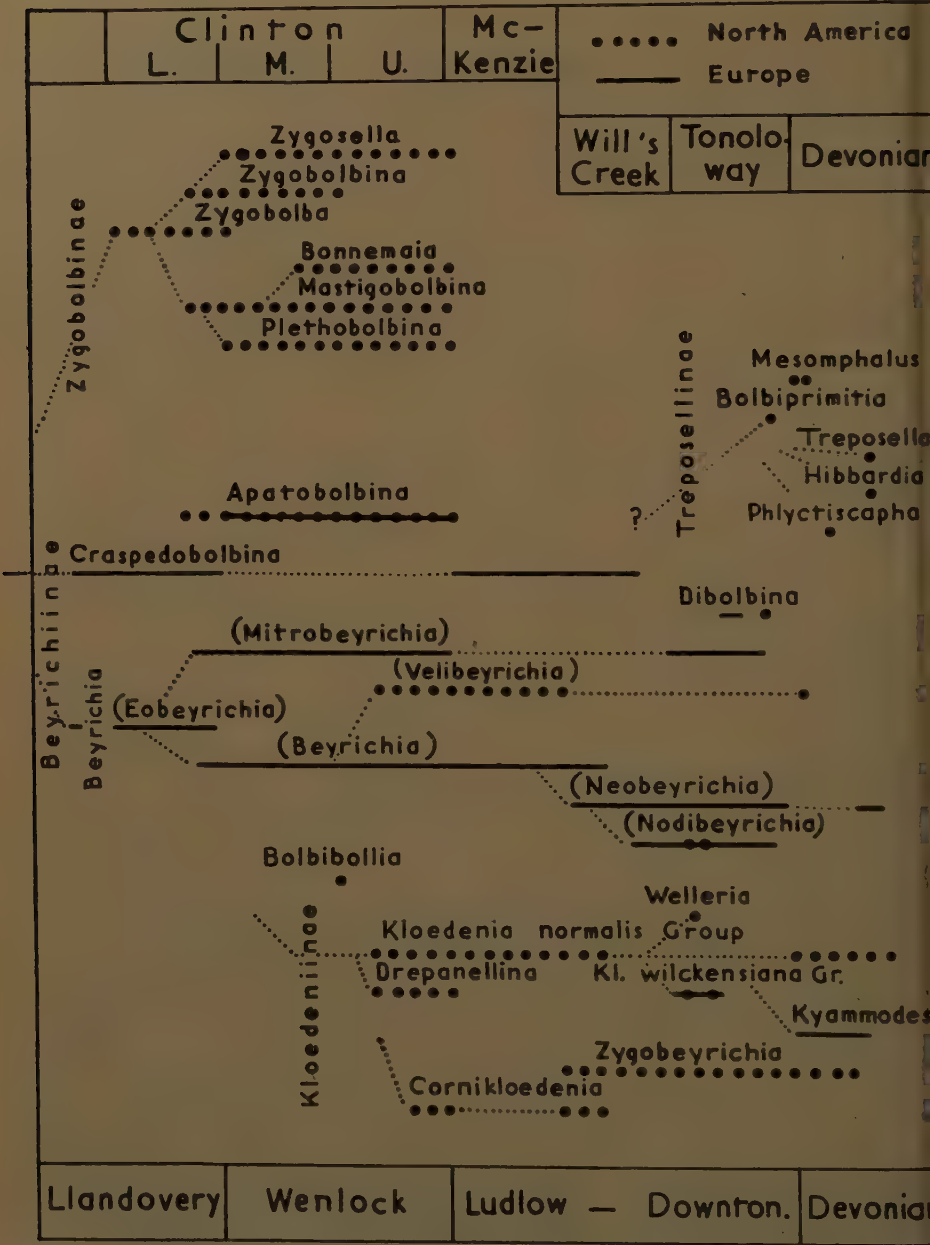

Fig. 4. Chart showing stratigraphical range of the Beyrichiidae.

beyrichiid type of pouch, although it does not seem very likely. The position of the genera *Bolbibollia* and *Dibolbina* is also uncertain at present. The rather late subfamily Treposellinae nov. may have developed from *Craspedobolbina.*

SYSTEMATIC DESCRIPTIONS.

An interrogation mark in front of the name of a systematic unit indicates that it is uncertain whether the unit really belongs to the next higher taxonomic unit.

Suborder PALEOCOPA HENNINGSMOEN 1953a.
Superfamily Beyrichiacea ULRICH & BASSLER 1953.[1]
Family Beyrichiidae JONES 1894.
Subfamily Beyrichiinae JONES 1894.
Genus *Beyrichia* McCOY 1846.
Subgenus *Eobeyrichia* subgen. n. (p. 22).

Type species: — *Beyrichia* (*Eobeyrichia*) *zygophora* sp.n.

Beyrichia (*Eobeyrichia*) *paucituberculata* sp.n.

Pl. 1, figs. 1—3; pl. 8, fig. 1.

Name: — The name *paucituberculata* alludes to the rather few tubercles of this species.

Type data: — Holotype is a left valve with pouch (P. M. O. no. 50821a) from 6b at Gunneklev near Porsgrunn (Skien—Langesund).

Diagnosis: — A small *Beyrichia* species with zygal ridge uniting L1 and Lp and an extra-lobate groove separating the lobate area from the extra-lobate area. Coarsely tuberculate. Only one row (rarely two rows) of tubercles developed between the lobes and the velate ridge.

Description: — This is based on 8 valves from 6b, preserved in limestone. The pouchless valves vary in size from 1.1 x 0.6 to 1.5 x 0.8 mm, and the two pouch-bearing valves found are 1.6 x 1.2 and 2.1 x 1.55 mm large. Trilobate. L1 is sickle-shaped. L2 forms an elongate node which is connected with Lp by a zygal ridge. A faint groove separates the lobate area from the rather narrow extra-lobate area, which carries one row of coarse tubercles. The velate ridge is ornamented with spines, and it is probable that at least some of the above-mentioned tubercles are spine-bases. L1 has one, and Lp has two «horns». The pouch is comparatively large, egg-shaped, and covered with scattered tubercles.

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[1] Type superfamily of the suborder Paleocopa.

Some valves from 6c β agree rather well with the material from 6b, but appear to obtain a slightly larger size, and the extra-lobate row of spines has a tendency to split into two rows.

Affinities: — This species is no doubt very close to, and may be a forerunner of *B.* (*Eobeyrichia*) *zygophora* sp.n.

Occurrence: — 6b Langesund—Skien (Gunneklev near Porsgrunn), 6c β Oslo—Asker (Slependen in Asker, Løkkåsen in Bærum), 6c β Holmestrand (Bjerkøya).

Beyrichia (*Eobeyrichia*) *zygophora* sp.n.

Pl. 1, figs. 4—9; pl. 8, fig. 2.

Name: — The name *zygophora* alludes to the yoke-like subsulcal ridge which this species carries.

Type data: — Holotype is a left valve without pouch (P. M. O. no. 53297a) from Slependen in Asker.

Diagnosis: — A *Beyrichia* species with zygal ridge, and an extra-lobate groove separating the lobes from the extra-lobate area. Coarsely tuberculate. Three or four rows of tubercles between the lobes and the velate ridge.

Decription: — This is based on 17 valves from 6c β, preserved in limestone. Valves without pouch vary in size from 2.0 x 1.8 to 2.4 x 1.5 mm. The length/height proportion varies between 1.1 and 1.5. A female valve is 2.7 x 1.8 mm. The valves are rather convex. Trilobate. L1 sickle-shaped. L2 forms an alongate node and is connected with Lp by a zygal ridge. A faint extra-lobate groove separates the lobes from the extra-lobate area. The lobes are densely covered with rather large tubercles. The extra-lobate area is densely covered with three or four rows of tubercles, and the velate ridge is likewise tuberculate. In some specimens it is seen that at least the tubercles in the velate ridge and some tubercles in the extra-lobal area are relly spine-bases. The pouch is elongate, and densely covered with tubercles

Affinities: — This species appears to be intermediate between *Beyrichia* (*Eobeyrichia*) *paucituberculata* sp.n. and *B.* (*E.*) *osloensis* sp.n.

Occurrence: — 6c β Oslo—Asker (Slependen in Asker).

Beyrichia (*Eobeyrichia*) *osloensis* sp.n.

Pl. 1, figs. 10—14; pl. 8, fig. 3.

Name; — This species is named after the Oslo Region.

Type data: — Holotype is a left valve without pouch (P. M. O. no. 42940) from 7b β at Ulvøya, Oslo.

Diagnosis: — A *Beyrichia* species with zygal ridge and a groove below Lp. Tuberculate. The extra-lobate area carries five or six rows of tubercles.

Description: — This is based on 12 valves from 7b β, preserved in limestone. The pouch-less valves reach a size of 2.15 x 1.60 mm. The two female valves present measured 2.35 x 1.80 and 2.35 x 1.90 mm. This species closely resembles *B. zygophora* sp.n., but differs in having a wider extra-lobate area, with five or six rows of tubercles. Furthermore, the extra-lobate groove is not so well developed anteriorly in *B.* (*E.*) *osloensis.*

A few valves in shale from 7c are not well preserved, but appear to belong to the same form as those in 7b β. A pouch-less valve measured 2.5 x 1.5 mm, and a valve with pouch was 2.6 mm long.

Affinities: — This species appears to be very close to *B.* (*E.*) *zygophora* sp.n., from which it may have developed.

Occurrence: — 7b β Oslo—Asker (Ulvøya; Malmøya; Malmøykalven), 7c Oslo—Asker (Gjettum in Bærum).

Beyrichia (*Eobeyrichia*) *skienensis* sp.n.

Pl. 1, figs. 15—16; pl. 8, fig. 4.

Name: — This species is named after the town of Skien.

Type data: — Holotype is a left valve without pouch (P. M. O. no. 51061) from 7a at Klammer'n, Skien.

Diagnosis: — A *Beyrichia* species with a narrow extra-lobate groove below L2 and Lp only, and a rather narrow zygal ridge between L2 and Lp. Tuberculate. The extra-lobate area carries about 4 rows of tubercles.

Description: — This is based on 9 valves from 7a, preserved in limestone. The pouch-less valves vary in size from 1.50 x 0.95 to 2.95 x 1.75 mm. No valves with pouch were encountered. This species resembles *B.* (*E.*) *zygophora* sp.n. and B. (*E.*) *osloensis* sp.n., but differs in having a rounder L2, and a narrower zygal ridge. Furthermore no groove is developed below L1. The tuberculation is somewhat more irregular in the present species, and may become rather indistinct. The valves are less convex than in the two above-mentioned species.

Affinities: — This species is no doubt closely related to *B.* (*E.*) *zygophora* sp.n. and *B.* (*E.*) *osloensis* sp.n. The narrow zygal ridge and the fading away of the extra-lobate groove point strongly towards the subgenus *Beyrichia*, which may have developed from the subgenus *Eobeyrichia* through forms like this by the loss of a zygal ridge and the reduction of the extra-lobate groove to the fissus.

Occurrence: — 7a Langesund-Skien (Klammer'n, Skien).

Subgenus *Beyrichia* McCoy 1846.

Beyrichia (*Beyrichia*) cf. *kloedeni* McCoy 1846.

Pl. 2, figs. 1—18; pl. 3, figs. 1—7; pl. 8, fig. 6.

1908 *Beyrichia* cf. *Klødeni* M'Coy — Kiær, p. 594.
1908 *Beyrichia* sp. sp. (pars) — Kiær, p. 594.

Remarks: — The material described below may belong to more than one species. The type material of *Beyrichia kloedeni* (redescribed by Straw, 1928) unfortunately is rather poorly preserved (cf. p. 23) thus preventing a detailed comparison with the present material. A number of subspecies and varieties of *Beyrichia kloedeni* have been described by various authors. Many of these forms are not even very well known, and some are probably not closely related to *B. kloedeni* at all. The present material seems to show that there is a great individual variation even between specimens on the same slab surface, a variation which appears to be greater than the differences between many of the subspecies and varieties described of *Beyrichia kloedeni*. The writer therefore refrains from assigning any of the present forms to *B. kloedeni* or any of its subspecies with certainty (with the exception of some specimens which are assigned to *B. kloedeni bicuspis* Kiesow 1888), and especially from erecting any new subspecies, which would probably only add to the confusion. Some of the richer occurrences are described below.

Material from 8d, Storøy, Ringerike.

Pl. 2, figs. 1—3.

Remarks: — The pouchless valve figured in Pl. 2, fig. 2 shows the surface ornamentation rather well, which consists of a very fine granulation with some scattered large tubercles. (This type of ornamentation is seen in all well preserved valves assigned to *B.* cf. *kloedeni* in the present paper). The fissus is clearly seen in this specimen, whereas neither the fissus nor, of course, the ornamentation is seen in the interior mould in Pl. 2, fig. 1.

Material from 9a, Gjeitøy, Ringerike.

Pl. 2, figs. 4—9.

Remarks: — All the figured specimens are from the same slab. There is a certain variation in the surface ornamentation and in the form of the lobes. The two female valves in figs. 6 and 7 show the presence of a lip-like ridge on the upper side of the fissus.

Material from 9a—b, Gjeitøy, Ringerike.

Pl. 2, figs. 10—12.

Remarks: — The three specimens figured are from the same slab. The specimen in fig. 11 shows a very faint tuberculation in the dorsal half of the valve. This material is probably conspecific with that from 9a.

Material from 9b, Gjeitøy, Ringerike.

Pl. 2, figs. 13—18.

Remarks: — The figured specimens are from three slabs (figs. 13 + 17; figs. 14 + 18; figs. 15 + 16), but all are from the same limestone bed. The figured specimens show the variation from rather tumid forms (fig. 15) via forms with more slender lobes and an antero-ventral depression (fig. 16) to forms with even more differentiated relief (fig. 17), which have a distinct antero-ventral depression, and the ventral end of Lp forming a knee-like inflation. The tubercles on the «knee» are larger than on the rest of the valve. Some specimens (figs. 15—18) show a tuberculation all over Lp, whereas others (figs. 13—14) show a distinct tuberculation only below the fissus. There is also a certain variation of the length/height proportion in these valves. This material is probably also conspecific with that from 9a.

Material from 9cα, Skjørvold, Ringerike.

Pl. 3, figs. 2—4.

Remarks: — These valves have the sulci reaching further down ventrally than those described above. The fissus has likewise a more ventral position. Figs. 3—4 are from the same slab surface. Fig. 4 shows an extremely short form (which is not due to any tectonic deformation, as it is associated with more normal valves, oriented in the same way in the rock).

Material from 9c, Langøya, Holmestrand.

Pl. 3, fig. 1.

Remarks: — This specimen agrees with the above from 9c, Skjørvold in having long sulci and a rather ventral position of the fissus. It probably belongs to the same form, and represents an extremely long type. Such long specimens occasionally occur together with more normal valves (as do the extremely short valves), and as they agree well in other features with the associated valves, they should be regarded as extremes of the length/height variation.

Material from 9d, Herøy, Ringerike.

Pl. 3, figs. 5—7.

Remarks: — These specimens have again shorter sulci and the fissus not situated so far down ventrally, thus reminding of the material from 9a and 9b. Fig. 6 shows a specimen with very faint tuberculation.

Remarks on the variations.

The examples above were given to illustrate the great variations of specimens probably belonging to the same species. Valves on one slab surface may have even belonged to one population. The writer has seen slab surfaces with up to about 100 valves, showing several kinds of variation, such as that from unusually long valves through the more common valves of intermediate length to unusually short valves, or from valves with distinct tuberculations to valves with indistinct tuberculation. In the latter case, usually the one or the other type is prevalent. This applies also to the variation from tumid valves to valves with more slender lobes. It is possible that the two latter cases have some connection with the environment where the animals lived. Even when the slender form is prevalent among the adult valves, the larval valves are usually of the tumid type.

Occurrence of *Beyrichia* cf. *kloedeni:* — 8b Ringerike (Bragsøy), 8c Ringerike (Storøy), 8c Oslo—Asker (Malmøya), 8d Oslo—Asker (Malmøya), 8d Ringerike (Storøy), 9a Oslo—Asker (Øverland in Bærum) 9a Ringerike (Gjeitøy), 9b Oslo—Asker (Øverland in Bærum; Fleskum in Bærum), 9b Holmestrand (Kommersøya), 9b Ringerike (Gjeitøy; Feikaråsen; Losetangen), 9c Holmestrand (Langøya), 9c Ringerike (Skjørvold; Utøy; Feikarodden), 9d Holmestrand (Langøya), 9d Ringerike (Herøy), 9e Ringerike (Øgårdsvika), 9f (Feikarodden), 9g Ringerike (Road section Kroksund—Vik; Rudstangen).

Beyrichia (*Beyrichia*) *kloedeni bicuspis* KIESOW 1888.

Pl. 3, figs. 8—10; pl. 8, fig. 7.

1888 *Beyrichia Klödeni* var. *bicuspis* mihi — KIESOW, p. 11, pl. II, figs. 6—7.
1908 *Beyrichia klœdeni bicuspis* KIESOW — ULRICH and BASSLER, p. 285.
1934 *Beyrichia bicuspis* (KIESOW) — BASSLER & KELLETT, p. 187.

Type data: — As lectotype is selected the right valve without pouch figured by KIESOW, 1888 (pl. II, fig. 7). It comes from horizon h at Kvarnberget near Slite in Gotland, Sweden.

Remarks: — The specimen shown in pl. 3, fig. 8 agrees very well with the lectotype, and also the specimen shown in fig. 9. The specimen shown in fig. 10 is comparatively much longer, but it occurs on the same slab surface as that in fig. 9. It probably represents an unusually long individual within the same subspecies, thus showing that a variation similar to that mentioned above may occur in this subspecies, too. It is not without hesitation that the writer uses the subspecific name *bicuspis*, as this form corresponds rather well with the slender-lobed specimens of *B*. cf. *kloedeni*. However, no intermediate forms between *B. kloedeni bicuspis* and the more tumid specimens assigned to *B*. cf. *kloedeni* were found in 9g. It is possible that more material will show that there are such transitional forms, but it is also possible that *B. kloedeni bicuspis* represents a seperate subspecies, which developed from earlier forms of *B. kloedeni* with greater variations.

Occurrence: — 9g Ringerike (Rudstangen).

Beyrichia (*Beyrichia*) *kiaeri* sp.n.

Pl. 3, figs. 13—15; pl. 8, fig. 8.

Name: — This species is named in honour of the late Professor, Dr. philos. Johan Kiær, who described the Silurian successions in the

Oslo Region, and who collected the greater part of the ostracod material described in this paper.

Type data: — Holotype is a left valve without pouch (P. M. O. no. S 2789) from 9c β at Langøya, Holmestrand.

Diagnosis: — A *Beyrichia* species with L1 more or less completely detached from L2 + Lp. L2 + Lp reach markedly further down on the valve than does L1. The fissus is developed well above the lower end of the sulcus.

Description: — This is based on a great number of valves from 9c β, preserved in limestone. Pouchless valves vary in size from 1.25 x 0.80 to 2.50 x 1.50 mm. A female valve measured 2.50 x 1.75 mm. Trilobate. Relief rather high. The node-like L2 is united with Lp ventrally to form a horseshoe-shaped ridge, which reaches much further down ventrally than the ventral end of L1. A well-developed antero-ventral depression is present in pouch-less valves. The fissus is situated rather high up on Lp, well above the ventral end of S2. The lobes are very finely granulose, with scattered larger tubercles. The velate ridge carries a row of spines, which are longest antero-ventrally.

Some valves from 8b agree rather well with the specimens from 9c β, but do not seem to obtain the same size. A female valve measured 2.15 x 1.55 mm.

Affinities: — This species appears to be intermediate between the subgenera *Beyrichia* and *Neobeyrichia*. As the anterior lobe is not as well detached from L2 + Lp as in *Neobeyrichia*, the present species is assigned to the subgenus *Beyrichia*. It appears rather probable that the subgenus *Neobeyrichia* developed from the subgenus *Beyrichia* through forms like *B.* (*B.*) *kiaeri* sp.n.

Occurrence: — 8b Ringerike (Bragsøy, Storøy), 9c β Holmestrand (Langøya).

Subgenus *Neobeyrichia* subgen. n. (cf. p. 25).

Type species: — *Beyrichia buchiana* Jones 1855.

Beyrichia (*Neobeyrichia*) *ringerikensis* sp.n.

Pl. 3, figs. 16—21; pl. 8, fig. 9.

1908 *Beyrichia* cf. *tuberculata* Boll — Kiær, p. 594.

Name: — This species is named after the district of Ringerike.

Type data: — Holotype is a right valve without pouch (P. M. O. no. 48659) from 9g in the road section Kroksund—Vik, Ringerike (pl. 3, fig. 19).

Diagnosis: — A *Beyrichia* species with L2 and Lp united to form a horseshoe-shaped ridge. L1 forms a conspicuous elongate node dorsally, but is very faint ventrally. Lp with a dorsal and a ventral node in its anterior part. Surface finely granulose, with scattered coarser granules. Velate ridge with stout spines.

Description: — This is based on about 50 valves from 9g, preserved in limestone. Pouchless valves vary in size from 0.65 x 0.40 to 2.40 x 1.40 mm. The pouch-bearing valves are usually broken, but one with entire outline measured 2.50 x 1.75. The velate spines are excluded in these measurements. This *Beyrichia* species is rather large, comparatively long, and with strong relief. Greatest height at midline; anterior end narrower than posterior end. The two sulci are well depressed; the median sulcus is wider and longer than the anterior sulcus. L1 forms dorsally an elongate node, but its ventral part is very faint. L2 is an elongate node, united ventrally with Lp. Lp carries (at least in large valves) two nodes, one at its dorsal end, and one ventrally. An antero-ventral depression is developed in pouch-less valves. The pouch is rather large and well defined. The velate ridge carried stout spines, which are largest antero-ventrally. There are 17 spines in the holotype. The ventral part of L1 and Lp (although usually not its two nodes) are ornamented with fine granules and some scattered coarser granules. Elsewhere the surface is smooth or only ornamented with fine granules.

Affinities: — *B.* (*N.*) *ringerikensis* sp.n. is probably close to *Beyrichia gotlandica* KIESOW 1888. The dorsal node on the posterior lobe seems to be smaller in *B. gotlandica*, and the ventral node does not seem to be developed. *B.* (*N.*) *ringerikensis* is no doubt close to *B.* (*B.*) *kiaeri* sp.n., from which it probably developed. L1 is faintly connected with L2 + Lp in *B.* (*N.*) *ringerikensis*, which might perhaps equally well have been assigned to the subgenus *Beyrichia*. The nodes on Lp point, however, towards the subgenus *Nodibeyrichia*, which appears to have developed from the subgenus *Neobeyrichia*. The whole appearance of this species is more «advanced» than in the subgenus *Beyrichia*.

Occurrence: — ?9f Ringerike (Feikarodden), 9g Ringerike (Road section Kroksund—Vik; Rudstangen; Grantorp).

Subgenus *Mitrobeyrichia* subgen.n. (cf. p. 27).

Type species: — *Beyrichia jonesii* BOLL 1856.

Beyrichia (*Mitrobeyrichia*) cf. *jonesii* BOLL 1856.

Pl. 3, figs. 11—12; pl. 8, fig. 5.

cf. 1856 *Beyrichia Jonesii* nov. sp. — BOLL, p. 322, figs. 1—2.
cf. 1869 *Beyrichia clavata* n.sp. — KOLMODIN, p, 18, fig. 10.
cf. 1934 *Beyrichia jonesii* BOLL — BASSLER & KELLETT, p. 195 (see this paper for further synonyms).
cf. 1934 *Beyrichia clavata* KOLMODIN — BASSLER & KELLETT, p. 189 (see this paper for further synonyms).
cf. 1936 *Beyrichia clavata* KOLMODIN — SWARTZ, p. 560, pl. 84, fig. 3d; p. 546, pl. 78, fig. 8g.
cf. 1940 *Beyrichia clavata* KOLMODIN — HARPER, p. 391, pl. IX, figs. 5—7.
cf. 1943 *Beyrichia jonesi* BOLL — KUMMEROW, p. 42, pl. 1, figs. 3, 10, 10a; pl. 2, figs. 9, 9a.
cf. 1943 *Beyrichia jonesi* BOLL var. *clavata* KOLMODIN — KUMMEROW, p. 44, pl. 1, fig. 7; pl. 2, figs. 10, 10a.
cf. 1951 *Beyrichia jonesi* BOLL — SPJELDNÆS, p. 745, pl. 103, figs. 1—11. (Claims that *B. clavata* is a synonym).

Type data: — The type material comes from glacial drift boulders in Northern Germany.

Remarks: — Two valves which may belong to this species occur in a limestone from 9d. The preservation is not too good, but they agree with *B. jonesii* in the main features, such as type of frill (narrow with thickened rim) and development of a zygal ridge. More and better material is needed to verify the identity with this species. The two valves measure 1.50 x 1.05 mm and 1.00 x 0.60 mm.

Occurrence: — 9d Holmestrand (Langøya).

Genus *Craspedobolbina* KUMMEROW 1924 (cf. p. 27).

Type species: — *Craspedobolbina dietrichi* KUMMEROW 1924, by original designation.

Remarks: — The four species described below all differ from the type species in having the pouch less well defined. The oldest of these species, *C. armata* sp.n., agrees otherwise rather well with the type species (cf. text fig. 5).

Craspedobolbina armata sp.n.

Pl. 4, figs. 1—4; pl. 8, fig . 10—11.

Name: — The name *armata* (armed) alludes to the posterior spine of the pouch.

Type data: — Holotype is a right female valve (P. M. O. no. 52974a) from 6c β at Slependen, Asker.

Diagnosis: — A *Craspedobolbina* species with a velate frill (restricted or entire) in the pouchless individuals. Female valves have a velate ridge and an antero-ventral pouch with a posterior spine (spur).

Description: — This is based on more than 100 valves from 6c β, preserved in limestone. Pouchless valves with restricted frill vary in size from 0.75 x 0.40 to 1.45 x 0.90 mm, whereas those with entire frill vary from 1.60 x 0.90 to 1.70 x 1.00 mm. Pouch-bearing valves vary in size from 1.50 x 0.95 to 1.55 x 1.05 m. Outline with slight forward swing. Both cardinal angles slightly obtuse. The sulcus reaches more than half way down the valve, and is slightly concave forwards. The pre-sulcal node (L2) is slightly elongate, and is connected with a faint zygal ridge in pouchless valves. L1 and Lp are confluent with the extralobate area, except dorsally where they each form a faint, curved plica. Pouchless valves have a velate frill. It is entire in some individuals, whereas in others it is restricted and runs from the anteriormost point of the valve to a little distance behind a point below the sulcus, where it climbs slightly higher up on the valve and ends rather abruptly. The female valves have instead a velate ridge and a rather large antero-ventral pouch. The posterior end of the pouch carries a spine (spur) below the sulcus. The surface of the valve (including pouch) is finely rugose. The frill is also rugose, parallel to its border. A few scattered granules are present mainly in the posterior lobe.

Valves from 6b and 7b β agree with the above description.

Affinities: — *Craspedobolbina armata* sp.n. agrees with the type species in being unisulcate, in having a median node, in being tuberculate, and in having a velate frill in pouchless valves and a velate ridge in valves with pouch. *C. armata* differs from it inter alia in having a less well-defined pouch, and in having a spine at the posterior end of the pouch. Nevertheless, these two species may be considered congeneric (cf. text fig. 5).

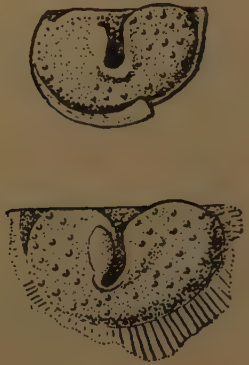

Fig. 5.

Above: *Craspedobolbina armata* sp.n. x 18. Form with short (restricted) frill.

Below: *Craspedobolbina dietrichi* (KUMMEROW 1924) x 30; redrawn after KUMMEROW, 1924, pl. 20 = 21, fig. 27.

Occurrence: — 6b Skien—Langesund (Gunneklev at Porsgrunn), 6b Hadeland (Bjertnes), 6c β Oslo—Asker (Slependen in Asker), 6c β Holmestrand (Bjerkøya), 7b β Oslo—Asker (Malmøya).

Craspedobolbina dorsoplicata sp.n.

Pl. 4, figs. 5—8; pl. 5, figs. 1—3; pl. 8, figs. 14—15.

Name: — The name *dorsoplicata* alludes to the well-developed dorsal plica (ridge) of this species.

Type data: — Holotype is a left female valve (P. M. O. no. 49675a) from 9d at Langøya, Holmestrand.

Diagnosis: — A *Craspedobolbina* species with short sulcus and well developed dorsal plica.

Description: — This is based on a great number of entire carapaces and separate valves from 9d, preserved in limestone. Pouchless valves vary in size from 0.55 x 0.30 to 1.50 x 0.90 mm, and pouch-bearing valves from 1.25 x 0.85 to 1.45 x 0.90 mm. Outline with subequal ends. Both cardinal angles obtuse. The short sulcus is situated behind a round presulcal node. Both sulcus and node may be rather well defined, or almost obsolete. Occasionally the sulcus may fork ventrally, and a small node-like swelling may then be present below the point of forking (pl. 4, fig. 7). A straight dorsal plica protrudes slightly above the hinge line. The length of the plica is somewhat less than 2/3 of the length of the hinge line. The hinge line is thus depressed, except at its ends. The velate ridge is separated from the marginal ridge by a shallow channel. The pouch is a rather large antero-ventral swelling, which is rather confluent with the rest of the valve. The left valve slightly overlaps the right valve ventrally. Surface smooth, or more less markedly reticulate.

Affinities: — *Craspedobolbina dorsoplicata* sp.n. is probably related to *C. armata* sp.n. even if the pouchless valves have no velate frill, only a velate ridge. *C. dorsoplicata* sp.n. is, on the whole, a more tumid species, and appears to be closest to *C. expansinodata* sp.n.

Occurrence: — 9c β Holmestrand (Langøya), 9d Holmestrand (Langøya), 9d Ringerike (Herøy).

Craspedobolbina expansinodata sp.n.

Pl. 4, figs. 9—17; pl. 8, figs. 12—13.

Name: — The name *expansinodata* alludes to the rather expanded presulcal node of this species.

Type data: — Holotype is a left female valve (P. M. O. no. 48710f) from 9c at Utøy, Ringerike.

Diagnosis: — A *Craspedobolbina* species with distinct sulcus, velate ridge, and rather expanded, round presulcal node.

Description: — This is based on a great number of valves from 9c, preserved in limestone. Pouchless valves vary in size from 0.40 x 0.20 to 1.65 x 1.00 mm, and pouch-bearing valves vary from 1.20 x 0.90 to 1.75 x 1.15 mm. Outline with faint forward swing. Anterior cardinal angle slightly obtuse, posterior cardinal angle right-angled. The sulcus is well defined and reaches slightly more than half way down the valve. The low presulcal node is round and rather large. A faint zygal ridge may be developed. A faint fissus-like groove parallel to the ventral margin may be present in the ventral half of the valve. The dorsal ridge is not very well developed. The velate structure is present as a thin and narrow ridge. A shallow channel separates it from the even narrower marginal ridge. The antero-ventrally situated pouch is comparatively large. The surface of the valve is reticulate (occasionally it appears pitted), but may be rather smooth, although a faint reticulation is always seen. The reticulation sometimes forms a fingerprint-like pattern (best seen in pl. 4, fig. 13).

Valves from 9d, 9f, and 9g agree with the above description.

Affinities: — *Craspedobolbina expansinodata* sp.n. appears to be closest to *C. dorsoplicata* sp.n., but does not have such a distinct dorsal plica. Furthermore, the sulcus in *C. expansinodata* sp.n. is longer, and the median node wider.

Occurrence: — 9c Oslo—Asker (Nes in Bærum), 9c Ringerike (Utøy), 9d Ringerike (Herøy), 9f Ringerike (Feikarodden), 9g Ringerike (Rudstangen; Grantorp; Road section Kroksund—Vik).

Craspedobolbina primitiva (VERWORN 1887).

Pl. 4, figs. 18—19; pl. 5, figs. 4—7; pl. 8, figs. 16—17.

1887 *Beyrichia primitiva* n.sp. — VERWORN, p. 28, pl. III, figs. 1—7, 9, 11
1889 *Beyrichia primitiva* — JONES, p. 382.
1889 *Beyrichia primitiva* VERWORN — KRAUSE, p. 16.
1891 *Beyrichia? primitiva* VERWORN — KRAUSE, p. 518.
1934 *Beyrichia primitiva* VERWORN — BASSLER & KELLETT, p. 203.

Type data: — As lectotype is chosen the female specimen figured by VERWORN, 1887 (pl. III, fig. 9) from a Silurian boulder found at Rixdorf near Berlin.

Diagnosis: — A smooth *Craspedobolbina* species with faint sulcus.

Description of present material: — This is based on a great number of separate valves, preserved in limestone. Pouchless valves vary in size from 0.65 x 0.40 to 1.80 x 1.15 mm, and pouch-bearing valves vary from 1.75 x 1.15 to 1.85 to 1.20 mm. Outline with forward swing. Both cardinal angles are obtuse. Hinge line slightly depressed. The sulcus is very faint or even absent. An extremely faint presulcal node may be seen. The sulcus is rather distinct in internal moulds. The margin is shallowly channeled, and a thin marginal ridge is developed. There is no velate ridge. The pouch is rather confluent with the rest of the valve, except interiorly, as it is better defined in internal moulds. The surface appears smooth, but may be slightly granulose on a small scale.

The above description applies to specimens from 9d, 9e, 9f, and 9g, and also agrees with the North German drift boulder specimens.

Affinities: — In spite of being practically non-sulcate and having no velate ridge, *Craspedobolbina primitiva* is probably closely related to *C. dorsoplicata* sp.n. and *C. expansinodata* sp.n. It evidently represents a «smooth» species of the genus. *C. primitiva* also resembles the non-sulcate *Phlyctiscapha rockportensis* KESLING 1953a, which, however, has an internal partition between the anterior part of the pouch and the rest of the valve. It is possible that they are related, but this is difficult to prove as «smooth» species of different genera often converge towards each other in appearance.

Occurrence: — 9d Ringerike (Herøy), 9e Ringerike (Ødegårdsvika), 9f Ringerike (Feikarodden), 9g Ringerike (Rudstangen; Road section Kroksund—Vik) — N. Germany (glacial drift boulder of Silurian age).

Genus *Apatobolbina* ULRICH & BASSLER 1923 (cf. p. 28).

Type species: — *Apatobolbina granifera* ULRICH & BASSLER 1923, by original designation.

Apatobolbina platygaster KUMMEROW 1924.

Pl. 5, figs. 8—13; pl. 8, fig. 20.

1924 *Apatobolbina platygaster* n.sp. — KUMMEROW, p. 428, pl. 21 (=20), figs. 29—31.

1934 *Apatobolbina platygaster* KUMMEROW — BASSLER & KELLETT, p. 162.

Type data: — As lectotype is chosen the left female valve figured by KUMMEROW, 1924 (pl. 21 = 20, fig. 31) from a glacial drift boulder (Encrinurus Limestone) in N. Germany.

Diagnosis: — A non-sulcate *Apatobolbina* species with very wide velate frill (about ½ the height of the valve inside the frill), with ovate muscle scar, and with a dorsal ridge. Surface granulose, at least in the ventral half of the valve.

Description of present material: — This is based on a great number of valves, preserved in limestone. Pouchless valves vary in size from 0.55 x 0.40 to 1.80 x 1.20 mm (including frill). Pouch-bearing valves are about 1.60 x 1.10 mm large (including frill and pouch). Outline with faint forward swing. Both cardinal angles obtuse. Non-sulcate. An ovate, smooth subcentral muscle scar is sometimes discernible, somewhat nearer to the frill than to the dorsal border. The lateral surface is pinched into a more or less distinct ridge dorsally, which is parallel to slightly more than the middle third of the hinge line, curves round at both ends, and fades away after a short distance. The most conspicuous feature is the rather wide frill, which does not quite reach the dorsal border at either end. The cross section of the frill is triangular, with a rather broad base. The lateral surface is smooth or with scattered small granules, especially in its ventral part. The muscle scar and two triangular areas at the cardinal angles are always smooth. The frill is striate and has also fine concentric rugae.

The egg-shaped pouch is seen to be formed by the velate ridge and is also finely rugose. The pouch opens into the main cavity of the valve. A low and narrow marginal ridge is separated from the lower side of the frill by a rather wide, but shallow channel.

The above description applies to specimens from 8a, 8b, 8c, 8d, 9a, and 9b. KUMMEROW'S specimens also agree with this description, except in that all his specimens were granulose.

Occurrence: — 8a Ringerike (Storøy), 8b Ringerike (Bragsøy, Storøy), 8c Oslo—Asker (Malmøya), 8d Ringerike (Sønsterud), 9a Oslo—Asker (Fleskum in Bærum), 9b Ringerike (Feikaråsen) — N. Germany (drift).

Family Primitiidae ULRICH & BASSLER 1923.

Remarks: — In his paper on the classification of straight-hinged ostracods, the writer (1953a) tentatively regarded the Primitiidae and Eurychilinidae as two separate subfamilies. Since then, the writer has seen more material of both groups, and he is now inclined to believe that may be united into one family. The Primitiinae and Eurychilininae may be regarded as two subfamilies of the Primitiidae. Apparently the subfamily Primitiinae developed from early eurychilinids. *Piretella* ÖPIK 1937 (and its probable synonym *Duhmbergia* SCHMIDT 1941) should probably also be included in the Primitiidae, perhaps in the separate subfamily Piretellinae ÖPIK 1937. The other genera which were assigned to this subfamily by HENNINGSMOEN (1953a), may be included in the subfamily Ctenonotellinae SCHMIDT 1941, which should not be transferred to the Primitiidae. The primitiopsiids were regarded as forming a subfamily of the Eurychilinidae by HENNINGSMOEN (1953a). It may be better to regard this group as a separate family, characterized by its posterior velate dimorphism. The position of the subfamily Euprimitiinae is still uncertain.

The following subfamilies may thus be included in the Primitiidae; Primitiinae, Piretellinae, Eurychilininae, and? Euprimitiinae.

Subfamily Eurychilininae ULRICH & BASSLER 1923

Genus *Platybolbina* HENNINGSMOEN 1953b.

Type species: — *Primitia distans* KRAUSE 1889 (cf. HENNINGSMOEN, 1954, p. 86).

Platybolbina tiara densistriata subsp. n.

Pl. 5, figs. 14—15; pl. 8, fig. 21.

Name: — The name *densistriata* alludes to the frill which is more densely striate than in *Platybolbina tiara tiara.*

Type data: — Holotype is the external impression of a right valve (P. M. O. no. 53314) from 6c *β* at Løkkåsen near Sandvika in Bærum.

Diagnosis: — Differs from *Platybolbina tiara* HENNINGSMOEN 1954 in having a more densely striate frill.

Description: — This is based on a few valves, external impressions, and internal moulds from 6c *β*, preserved in shale. The measureable specimens are between 1.50 x 0.85 mm and 1.60 x 0.90 mm large. Outline with forward swing. Anterior cardinal angle obtuse, posterior cardinal angle right-angled. Only a short, pit-like sulcus and a very small presulcal node is developed. The frill is entire, rather wide, and densely radially striate. The width of the frill seems to vary, but no specimens with incurved frill were seen. This may, however, be very well due to the small number (4) of specimens showing the frill. The surface of the valve is finely granulose.

Remarks; — This form is probably very close to the Upper Ordovician *Platybolbina tiara.*

Occurrence: — 6c *β* Oslo—Asker (Malmøya; Løkkåsen near Sandvika in Bærum).

Platybolbina lunulifera sp.n.

Pl. 6, figs. 1—4, pl. 8, fig. 22.

Name: — The name *lunulifera* alludes to the crescent-shaped frill of the female valves.

Type data: — Holotype is a left female valve (P. M. O. no. 48062d) from 9d at Herøy, Ringerike.

Diagnosis: — A *Platybolbina* species with dimorphic velate ridge, which is radially striate and does not reach the dorsal border at either end. Non-sulcate, but with a subcentral, smooth muscle scar. Surface pitted.

Description: — This is based on 5 separate valves from 9d, preserved in limestone; two valves of the male type (1.10 x 0.50 and 1.15 x 0.65 mm) and three female valves, varying in size from 1.50

(restored) x 0.95 mm to 1.60 x 1.05 mm. Elongate, with subequal ends. Both cardinal angles obtuse. Non-sulcate. A subcentral muscle scar is visible as a smooth spot much closer to the frill than to the dorsal border. The velate frill is finely radially striate, and does not reach the dorsal border at either end. In valves of the male type it is flat and rather narrow, in valves of the female type it is wide (about 0.2 mm wide where it is widest) and convex. The surface of the valve (excepting the muscle scar and the frill) is fairly coarsely pitted.

A few separate valves from 9c and 9g agree well with the material described above, and reach the same size. The smallest female valve encountered in 9g measures 1.35 x 0.85 mm.

Remarks: — *P. lunulifera* sp.n. resembles Ordovician forms like *P. elongata* (KRAUSE 1891), but differs from this i. a. in having a convex frill in female valves, a feature which, however, is known in other Ordovician species. The Lower Carboniferous *P. praetexta* (KUMMEROW 1939) is another non-sulcate species. Probably only the male type of this form has been described.

Occurrence: — 9c Ringerike (Utøy), 9d Ringerike (Herøy), 9g Ringerike (Rudstangen; road section Kroksund—Vik).

Platybolbina? bulbosa sp.n.

Pl. 5, figs. 16—21; pl. 8, fig. 23.

Name: — The name *bulbosa* alludes to the two bulb-like L2's of each carapace.

Type data: — Holotype is a right valve (P. M. O. no. 42945e) from 7b *β* at Ulvøya, Oslo.

Diagnosis: — A *Platybolbina*-like species with fairly wide, entire, and radially striate frill, *Beyrichia*-like lobation, and prominent bulb-like L2. Surface finely granulose with some scattered coarser granules.

Description: — This is based on more than 20 valves from 7b *β*, preserved in limestone. They vary in size from 0.80 x 0.60 mm to 1.60 x 1.05 mm. Outline with forward swing. Both cardinal angles obtuse. Bisulcate. L1 low, crescent-shaped, protruding slightly above hinge line, where it forms a short, curved plica. L2 bulbous, unusually high. A faint zygal ridge connects it with L3, which is low and protrudes slightly above the hinge line, where it forms a dorsal plica. S1 rather shallow and narrow, S2 well developed. An entire, rather wide velate frill is developed. The surface of the valve (excepting frill) is finely granulose, with some scattered coarser tubercles.

Remarks: — No dimorphism was observed, but the material is too scanty to exclude the possibility of finding such. If this species developed a pouch of the beyrichiid type, it should no doubt be placed in the Beyrichiidae. *P.? bulbosa* reminds one of valves of the male type of *Beyrichia* and *Craspedobolbina*. Since no pouch-bearing individuals were found, it may tentatively be regarded as a bisulcate *Platybolbina* species, recalling such species as *P. umbonata* (KRAUSE 1892).

Occurrence: — 7a Holmestrand (Bjerkøya), 7b β Oslo—Asker (Malmøya).

?Subfamily Euprimitiinae HESSLAND 1949.

?Genus *Primitiella* ULRICH 1894.

Type species: — By original designation, *Primitiella constricta* ULRICH 1894.

Primitiella? cf. *parallela* (KUMMEROW 1924).

Pl. 6, figs. 9—10; pl. 8, fig. 18.

cf. 1924 *Primitia parallela* n.sp. — KUMMEROW, p. 422, pl. 20 (=21), fig. 18.
cf. 1934 *Primitia parallela* KUMMEROW — BASSLER & KELLETT, p. 452.
cf. 1941 *Primitia parallela* KUMMEROW — TRIEBEL, p. 309, pl. 1, fig. 3.

Type data: — Holotype (by monotypy) is the left valve figured by KUMMEROW (1924) from a Silurian drift boulder in N. Germany.

Description of present material: — This is based on 8 valves, preserved in limestone. The valves vary in size from 1.5 x 0.8 mm to 1.8 x 1.0 mm. Elongate outline, with subequal ends. Both cardinal angles obtuse. Ventral border almost parallel to dorsal border; posterior half of the valve only slightly higher than the anterior half. Moderately convex. A deep sulcal pit is developed, and dorsal to this there is a faint sulcoid depression. In front of the sulcal area there is a very low presulcal node, which is distinguishable from the rest of the valve mainly due to it being encircled by depressions. A small pit-like depression is present antero-ventrally to this «node». A narrow ridge is developed along the free borders. The surface appears smooth. A strange pattern is sometimes seen inside the shell (cf. next species).

Remarks: — The present specimens resemble *Primitiella? parallela:* however, the only known specimen of this species is smaller (0.72 x 0.35 mm), has a very fine reticulation, appears to be highest in its anterior half, and seems to have more pit-like depressions in front of the «node». It is possible that it is a larval valve of the present form.

Occurrence: — 6b Skien—Porsgrunn (Gunneklev), 6c *β* Oslo—Asker (Løkkåsen near Sandvika in Bærum).

Primitiella? bipunctata sp.n.

Pl. 6, figs. 7—8, 11; pl. 8, fig. 19.

Name: — The name *bipunctata* alludes to the two sulcal pits.

Type data: — Holotype is a right valve (P. M. O. no. 53300b) from 6c*β* at Slependen in Asker.

Diagnosis: — Valves elongated (length/height: 1.5—1.9), ventral border almost parallel to the dorsal border. Presulcal node more or less distinct, connected with a horizontal ridge separating two sulcal pits.

Description: — This is based on 5 valves, preserved in limestone. The valves vary in size from 1.7 x 0.9 to 1.9 x 1.0 mm. Length/height proportion varies from 1.5 to 1.9. Elongated outline with subequal ends. Ventral border almost parallel to dorsal border. Moderately convex. Two sulcal pits, one above the other, are separated by a short horizontal ridge, which is anteriorly united with a small presulcal node. The node may be more or less well developed. Free borders with a narrow submarginal ridge. The surface appears smooth.

The shell may show a peculiar pattern when wetted or partly weathered (pl. 6, fig. 11). When a valve (which is not too dark) is wetted, there appears a system of dark vertical ridges, separating vertical rows of light spots. In a weathered specimen the dark lines appear as ridges, and the spots as pits. As both the inner and outer surface of the valve is smooth (as can be seen in internal and external impressions), the pattern seems to be due to the internal structure of the shell substance. The same sort of pattern was also observed in *P.?* cf. *parallela.*

Remarks: — As long as the type species of *Primitiella* is not too well known, it appears best to assign the present species only tentatively to *Primitiella*.

Occurrence: — 6c β Holmestrand (Bjerkøya), 6c β, Oslo—Asker (Malmøya; Slependen).

Familiae incertae.

Genus *Halliella* Ulrich 1891.

Type species: — *Halliella retifera* Ulrich 1891, subsequent designation by Miller (1892, p. 707), cf. Warthin (1948, p. 646).

Halliella? seminulum (Jones 1855).

Pl. 6, fig. 12; pl. 8, fig. 24.

1855 *Beyrichia seminulum* n.sp. — Jones, p. 173, pl. 6, fig. 24.
1934 *Halliella seminulum* (Jones) — Bassler & Kellett, p. 323. (See this paper for earlier synonyms).

Type data: — As lectotype is chosen the specimen figured by Jones (1855) from the Wenlock of Montgomeryshire.

Remarks: — The present specimens agree with the specimen figured by Krause (1892, pl. 22, fig. 3) in having the pits below the sulcus united into a little groove. It is possible that this form should be separated from *H.? seminulum* (Jones). The generic position of *H.? seminulum* is uncertain. It differs from *H. retifera* inter alia in having much better defined sulcus. Only 7 specimens of *H.? seminulum* have been met with in the Norwegian material.

Occurrence: — 9c Ringerike (Utøy), 9c β Holmestrand (Langøya), 9g Ringerike (Road section Kroksund—Vik) — Great Britain (Wenlock), Sweden (Fröjel in Gotland), N. Germany (drift), Arctic America (Beechey Island).

Family Hollinidae Swartz 1936.

Genus *Parabolbina* Swartz 1936.

Type species: — By original designation, *Ctenobolbina granosa* Ulrich 1900.

Parabolbina diensti (KUMMEROW 1924).

Pl. 6, figs. 5, 6?; pl. 8, fig. 30.

1924 *Ctenobolbina Diensti* n.sp. — KUMMEROW, p. 431, pl. 21 (=20), fig. 8.
1933 *Ctenobolbina diensti* KUMM. — KUMMEROW, p. 47, text fig. 5.
1934 *Ctenobolbina diensti* KUMMEROW — BASSLER & KELLETT, p. 250.
1940 *Ctenobolbina diensti* KUMMEROW — HARPER, p. 393, pl. IX, fig. 10.
1941 *Ctenobolbina diensti* KUMMEROW — TRIEBEL, p, 361.
1941 *Ctenentoma diensti* (KUMMEROW) — SCHMIDT, p. 36.
1943 *Ctenobolbina diensti* KUMM. — KUMMEROW, p. 47, pl. 1, fig. 13.
1948 *Ctenobolbina*(?) *diensti* KUMMEROW — KUMMEROW, p. 21.

Type data: — As lectotype is chosen the female valve figured by KUMMEROW (1924) from a glacial drift boulder of Silurian «Graptolithengestein» in Northern Germany.

Description of present material: — This is based on two female valves, measuring 1.0 x 0.65 mm, preserved in limestone. Unisulcate, sulcus with geniculum. Upper part of sulcus rather deep and wide and rather straight. Ventral part of sulcus faint and narrower, curving forwards and back again. A rather small but distinct presulcal node is present in front of the deepest part of the sulcus. A node-like swelling is developed in the posterior lobe just behind the uppermost part of the sulcus. A rather wide (0.25 mm) velate frill of an anteroventral position ends abruptly in both ends. It carries a fine marginal ridge, and its surface is undulating, producing 5 buckles, one behind the other as beads on a string. The frill is finely striate, even across the buckles which do not reach the outer border of the frill. The surface of the rest of the valve is finely granulose.

Some small frill-less valves (pl. 6, fig. 6) occur together with the above-described form, and may possibly represent young valves. Their surface is reticulate.

Remarks: — The present material seems to agree rather well with the German drift material, and apparently also with the British material. KUMMEROW (1924, 1933, 1943, 1948) has suggested that the buckles of the frill were brood spaces. The peculiar frill of this specimens reminds one of *Parabolbina*. Its sulcus, widening slightly ventrally, also recalls the Hollinidae, and the species is placed here in *Parabolbina*. It may be rather close to species like *P. parvinoda* SWARTZ & SWAIN 1941.

Occurrence: — 9d Holmestrand (Langøya) — N. Germany (drift), England (Upper Valentian, Shropshire).

Family Primitiopsiidae Swartz 1936[1].

Genus *Primitiopsis* Jones 1887.

Type species: — By original designation, *Primitiopsis planifrons* Jones 1887.

Remarks on the type species: — Examination of the material of *P. planifrons* from the type locality, Fröjel, and from Mulde, Gotland, shows that the species is trimorphic. The material comprises of some 250 valves and carapaces. The greater part belongs to a non-velate form (male type) ranging in size from 0.50 x 0,35 to 1.30 x 0.90 mm. It is more swollen ventrally than the other forms. A form with narrow posterior velum (young female valves?) is rarer. In an entire carapace the two velae diverge. This form varied in size from 0.80 x 0.60 to 1.10 x 0.80 mm. Only two valves and a carpace were found of the third form, which has a wider posterior velum. In an entire carapace the two velae meet posteriorly to form a posterior pouch. The smaller specimen measured 1.40 x 0.85 mm and the larger 1.50 x 0.95 mm. This form may represent mature females. None of the specimens show a longitudinal striation of the velum as shown in the drawing of the specimen given by Jones (1887, p. 5).

In the smallest specimens the subcentral pit lies almost midway between the anterior and posterior border. In larger specimens the pit is markedly closer to the non-velate end. It appears reasonable to assume that the pit migrates forwards during the ontogenetical development, just as the muscle scar migrates forwards in recent ostracods (cf. Claus, 1886). This supports the view that the velate structure of *Primitiopsis* is situated posteriorly.

The specimens from Fröjel, Gotland, assigned to *Primitia valida* Jones & Holl 1886 by Jones (1887, p. 4; 1888. p. 405) probably represent the form which is regarded here as the male type of *Primitiopsis planifrons*. *Primitia reticristata* Jones 1887 (cf. also Jones, 1888, pl. XXII, figs. 15a—c) may possibly represent what is suggested here to be young female specimens of *Primitiopsis planifrons*. It seems reasonable to assume that *Primitia cristata* Jones & Holl 1865, with a narrow posterior frill, should also be assigned to *Primitiopsis*.

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[1] Cf. p. 52.

Primitiopsis cf. *planifrons* Jones 1887.

Pl. 6, figs. 16—19; pl. 8, fig. 28.

cf. 1887 *Primitiopsis planifrons* sp. nov. — Jones, p. 5, text fig. p. 5.
cf. ?1887 *Primitia valida* J. & H. — Jones, p. 4.
cf. ?1887 *Primitia reticristata* sp. nov. — Jones, p. 5.
cf. 1888 *Primitiopsis planifrons* Jones — Jones, p. 406, pl. XXII, figs. 18a—d.
cf. ?1888 *Primitia valida* J. & H. — Jones, p. 405.
cf. ?1888 *Primitia reticristata* Jones — Jones, p. 406, pl. XXII, figs. 15a—c.
cf. 1917 *Primitiopsis planifrons* Jones — Hede, pp, 24, 29.
cf. 1921 *Primitiopsis planifrons* Jones — Hede, p. 98.
cf. ?1921 *Primitia valida* Jones & Holl — Hede, p. 98.
cf. ?1921 *Primitia reticristata* Jones — Hede, p. 98.
cf. 1923 *Primitiopsis planifrons* Jones — Ulrich & Bassler, p. 299, text fig. 15 (figs. 7—9).
cf. 1933 *Primitiopsis planifrons* Jones — Bonnema, p. 34, figs. 26—28.
cf. 1934 *Primitiopsis planifrons* Jones — Bassler & Kellett, p. 466, text fig. 6 (figs. 7—9).
cf. ?1934 *Primitia valida* Jones & Holl (pars) — Bassler & Kellett, p. 459.
cf. ?1934 *Primitia reticristata* Jones — Bassler & Kellett, p. 454.
cf. 1936 *Primitiopsis planifrons* Jones — Swartz, p. 555, pl. 83, figs. 1a—b.
cf. 1953a *Primitiopsis planifrons* Jones — Henningsmoen, p. 230.

Type data: — As lectotype of *Primitiopsis planifrons* is selected the pouch-bearing valve figured by Jones (1887, p. 5) from Fröjel in Gotland, Sweden.

Remarks: — About 30 valves have been found which resemble *Primitiopsis planifrons* quite a lot. However, only two of the three forms described above have been observed, namely the non-velate form (here ranging in size from 0.55 x 0.30 to 0.90 x 0.65 mm) and the form with a narrow and flat posterior frill (4 specimens, all about 0.90 x 0.65 mm). No pouch-bearing form has been found. Since this form seems to be rather rare in the Gotland material, too, it is possible that it will also eventually be found in the Norwegian material. The present specimens are not so strongly pitted as the Gotland material, and sometimes the surface ornamentation is almost effaced.

Occurrence: — 9c Ringerike (Utøy), 9c γ Holmestrand (Langøya), 9d Holmestrand (Langøya), 9d Ringerike (Herøy), 9f Ringerike (Feikarodden), 9g Ringerike (Rudstangen, Road Kroksund—Vik).

Primitiopsis dorsoplicata sp.n.

Pl. 6, figs. 13—15; pl. 8, fig. 29.

Name: — The name *dorsoplicata* alludes to the well developed dorsal plica of this species.

Type data: — Holotype is a right valve (P. M. O. no. 48635a) from 9g in the road section Kroksund—Vik, Ringerike.

Diagnosis: — A smooth, non-sulcate *Primitiopsis* species with distinct dorsal plica. A velate frill is present posteriorly in some specimens; it diminishes forwards ventrally. In other specimens it is substituted with a velate ridge.

Description: — This is based on some 30 separate valves from 9g, preserved in limestone. They are between 0.70 x 0.50 and 0.80 x 0.55 mm large. Outline with subequal ends (disregarding posterior frill); cardinal angles slightly obtuse. Nonsulcate. In one specimen a small pit was observed, corresponding to the sulcal pit in *P. planifrons*. Lateral surface moderately convex, dorsally pinched into a ridge (dorsal plica), protruding above the hinge line. The dorsal border of this plica is convex. A flat velate frill is developed posteriorly and partly ventrally in some specimens. The frill is widest posteriorly, and diminishes gradually forwards. In other specimens the frill is replaced by a velate ridge only. The marginal border is faintly channeled. A tuberculate ridge is developed between the velate structure and the free edge. The surface of the valve is smooth.

Occurrence: — 9c γ Holmestrand (Langøya), 9c Ringerike (Utøy), 9f Ringerike (Feikarodden), 9g Ringerike (Rudstangen; Grantorp; Road section Kroksund—Vik).

?Signetopsis gen.n.

Name: — The name *Signetopsis* alludes to the signet-like appearance of the valves of this genus.

Type species: — *Signetopsis quadrilobata* sp.n.

Diagnosis: — A beyrichiacean ostracod genus with short median sulcus (S2). Quadrilobate to bilobate. A small comma-like ridge is developed behind and below the deep pit-like ventral part of S2, and is fused with L2 ventrally. Frill entire and confluent with a dorsal crest, thus forming a closed subelliptical submarginal frill. The frill is widest posteriorly, where it appears to be dimorphic.

Remarks: — The following species may be included in *Signetopsis:*

Beyrichia lacunata JONES & HOLL 1886 (Wenlockian, England).

Bollia semicircularis KRAUSE 1891 (Silurian drift, N. Germany; Ludlovian, Norway).

Bollia rotundata KRAUSE 1891 (Silurian drift, N. Germany; Ludlovian, Norway).

Jonesites reticulatus HARPER 1940 (Upper Valentian, England).

Signetopsis quadrilobata sp.n. (Ludlovian, Norway).

Signetopsis malornata sp.n. (Ludlovian, Norway).

All these species are no doubt closely related. It is interesting that even in the bilobate species traces of the anterior and posterior lobe may often be seen. This genus is another good example of how closely related species may have a different degree of lobation (cf. HENNINGSMOEN, 1953a, p. 190).

Affinities: — *Signetopsis* resembles genera like *Bollia* and *Jonesites*, but differs from these i. a. in having the characteristic small comma-like ridge below and behind the pit-like ventral end of the median sulcus. *Signetopsis* has a frill which appears to be dimorphic posteriorly. If so, *Signetopsis* may be related to *Primitiopsis*. In this connection it is of interest that *Primitiopsis*, too, may have a dorsal ridge, and that some species, like *Primitiopsis planifrons* (the type species), have a sulcal pit corresponding to the pit-like ventral end of the median sulcus in *Signetopsis*. For the above reasons *Signetopsis* is tentatively assigned to the family Primitiopsiidae.

Signetopsis quadrilobata sp.n.

Pl. 7, figs. 1—9; pl. 8, fig. 25.

Name: — The name *quadrilobata* alludes to the four lobes of this species.

Type data: — Holotype is a left valve (P. M. O. no. S 2791d) from 9c β at Langøya, Holmestrand.

Diagnosis: — A quadrilobate *Signetopsis* species. L1 and L2 do not meet dorsally. Surface punctate.

Description: — This is based on some 50 separate valves from 9c β, preserved in limestone. Valves of both types (narrow or wide posterior frill) vary in size from 0.60 x 0.40 to 0.75 x 0.45 mm. The lobate ridges form a quadrilobate pattern, which may vary slightly in size in relation to the lateral surface of the valve, and in minor details in the course of the ridges. L1 and L2 never unite dorsally. None of these ridges usually reach the dorsal border; L2 may occasionally do so. The lenght of L4 may vary. When it is long, it curves towards L3 dorsally, but never reaches it. The faint median sulcus behind L2 ends ventrally in a deep pit. The comma-like ridge behind and below this pit is well developed. The velate ridge is united with a dorsal ridge, thus enclosing the lateral surface. In some valves (female valves?) the velate structure is developed as a frill posteriorly and postero-ventrally. A narrow marginal ridge is separated from the velate ridge by a shallow channel. The lateral surface is finely pitted, except the lobes and ridges which are smooth.

Affinities: — This species is no doubt closely related to *Signetopsis lacunata* (JONES & HOLL 1886), which, however, has L1 and L2 united dorsally to from a loop.

Occurrence: — 9c β Holmestrand (Langøya).

Signetopsis semicircularis (KRAUSE 1891).

Pl. 7, figs. 10—15, 16?; pl. 8, fig. 26.

1891 *Bollia semicircularis* n.sp. — KRAUSE, p. 497, pl. XXXI, figs. 8—9.
1891 *Bollia rotundata* n.sp. — KRAUSE, p. 497, pl. XXXI, fig. 10.
1934 *Bollia semicircularis* KRAUSE — BASSLER & KELLETT, p. 219.
1934 *Bollia rotundata* KRAUSE — BASSLER & KELLETT, p. 219.

Type data: — As lectotype is chosen the carapace figured by KRAUSE (1891, pl. XXXI, fig. 8) from a glacial drift boulder of Silurian limestone in N. Germany.

Diagnosis: — A bilobate *Signetopsis* species where the two lobes form a U-shaped ridge (L2 + L3), with the comma-like ridge inside it. Surface smooth.

Description: — This is based on more than 100 separate valves, preserved in limestone. They vary in size from 0.55 x 0.40 to 0.75 x 0.45 mm. Bilobate. L2 and L3 form a U-shaped ridge which is well defined. A tiny comma-like ridge is developed behind and below the sulcal pit, and is united with L2. The ventral part of the U-shaped ridge may, occasionally, be prolonged anteriorly and posteriorly (traces of L1 and L4). A valve showing a distinct quadrilobate pattern (pl. 7, fig. 16) should probably be included in this species (apart from having 4 lobes it resembles *S. semicircularis* more than *S. quadrilobata,* i. a. in being smooth). The velate ridge is well defined and confluent with the dorsal ridge, together forming a closed, subelliptical ridge. The area inside this ridge is slightly narrower anteriorly than posteriorly. The dorsal ridge is connected with the dorsal ends of L2 and L3. The velate ridge is usually convex also in its posterior part (pl. 7, fig. 13). In some (female?) valves it is flattened and more frill-like posteriorly (pl. 7, fig. 12). The surface of the valve is smooth. The length/height proportion varies between 1.4 and 1.6. The comparatively high valves (pl. 7, fig. 15) agree rather well with *S. rotundata* (KRAUSE 1891), which is based on one specimen, and is possibly a synonym of *S. semicircularis* with which it occurs.

Affinities: — The Norwegian form agrees very well with the German drift species, and there can hardly be any doubt that they are conspecific. The Upper Valentian form *S. reticulata* (HARPER 1940) from England resembles *S. semicircularis,* but is reticulate. Furthermore L2 and L3 do not quite unite to form a U-shaped ridge. The holotype of *S. reticulata* (HARPER 1940, pl. IX, fig. 9) is not too well preserved. A better specimen is seen in the slab (Geological Survey Museum, London, no. 70332) containing the syntype of *Kloedenia salopiensis* figured by HARPER (1940, pl. IX, fig. 11).

Occurrence: — 9c Ringerike (Skjørvold), 9c Oslo—Asker (Nes in Bærum), 9d Holmestrand (Langøya), 9d Ringerike (Herøy), 9f Ringerike (Feikarodden), 9g Ringerike (Rudstangen; Grantorp; road-cut Kroksund—Vik) — Glacial drift boulder of Silurian limestone in N. Germany.

Signetopsis malornata sp.n.

Pl. 7, figs. 17—22; pl. 8, fig. 27.

Name: — The name *malornata* alludes to the rather diffuse and restricted lobal pattern of this species.

Type data: — Holotype is a left valve (P. M. O. no. S 2791m) from 9c β at Langøya, Holmestrand.

Diagnosis: — A bilobate *Signetopsis* species with pitted (reticulate) surface. The lobes (L2, L3) are rather diffuse, and not united ventrally.

Description: — This is based on more than 100 separate valves preserved in limestone. The valves of the male (?) type vary in size from 0.60 x 0.30 to 0.90 x 0.60 mm, and those of the female (?) type vary from 0.75 x 0.45 to 0.95 x 0.60 mm. The anterior end is distinctly narrower than the posterior end. Bilobate. L2 and L3 are not united ventrally, though the ventral end of L3 may curve for a short distance towards L2. The comma-like ridge behind and below the sulcal pit is well developed. Traces of the ventral end of L1, and also a short ridge dorsal to it, may be united with L2 (pl. 7, fig. 22). The velate structure is confluent with the dorsal ridge, and is usually developed as a narrow frill (pl. 7, figs. 17, 18) (male type?). In some (female?) valves the posterior part of the frill is markedly wider (pl. 7, figs. 20, 22). Even a third form may occur, with no velate frill (pl. 7, fig. 21 — which is not an internal mould). The surface is densely punctate (reticulate). In some specimens the pits are rather indistinct.

Affinites: — *S. malornata* resembles *S. semicircularis* and *S. reticulata*, but L2 and L3 do not form a U-shaped pattern and are more diffuse. *S. malornata* is also somewhat larger.

Occurrence: — 9c Ringerike (Utøy; Skjørvold), 9c Holmestrand (Langøya), 9g (Rudstangen; Grantorp; road-cut Kroksund—Vik).

REMARKS ON THE STRATIGRAPHY.

The symbols now in use for the Silurian successions in the Oslo region were introduced by KIÆR in 1906. All units denoted by a figure and one or two letters (as 6a, 9cβ) were called zones by him, and in most cases named after a fossil, but not always, as 8d = the zone with the Malmö (=Malmøy) Limestone. Most of his zones are, however, based on lithology. A few zones have the same lithology as the under- or overlying zone (as 7cγ in the Mjøsa area) and are based only on their fossils.

It is obviously unpractical that some of the symbols are used for litho-stratigraphic units and others for bio-stratigraphic units. It would probably be the best to let the symbols denote bio-stratigraphic units only. This would require a revision of the Silurian successions in the Oslo region. As such a revision is outside the scope of this paper, the symbols are used here in KIÆR'S sense. As the correlations between areas within the Oslo region may require smaller adjustments, the lower and upper boundaries of e.g. 8c in one area need not correspond exactly in time to those of 8c in another area.

Four series (called «Etagen» by KIÆR in 1906) are recognized in the marine Silurian of the Oslo region, namely series 6 (or Stricklandia Series), Series 7 (Pentamerus Series), Series 8 (Eospirifer plicatellus Series), and Series 9 (Delthyris elevatus Series). KIÆR refers to Series 6 and 7 as Llandovery, Series 8 as Wenlock, and Series 9 as Ludlow. When comparing the Norwegian and British successions, however, he assigns 9a and 9b to the Wenlock Series, and this is also done here. There is a gradual transition from 9g into the overlying Ringerike Sandstone (= Series 10), the so-called Downtonian sandstone which may possibly also include the top of the Ludlow Series, and which contains no marine fossils.

REMARKS ON THE DISTRIBUTION OF SILURIAN BEYRICHIACEA IN THE OSLO REGION.

A chart (p. 67) shows the known distribution of Silurian Beyrichiacea in the Oslo region. The Cambro-Silurian areas in the Oslo region are shown in a map published by STØRMER (1953, p. 53). The present investigation is based mainly on material from rock samples which were primarily collected because of their content of macrofossils. As the collections are much richer from some areas than from others, this probably explains why only 5 Silurian areas in the Oslo region are represented. No doubt a systematical search for ostracods would show that they had a greater geographical distribution than appears from this chart, and would probably also adjust their vertical range.

The Llandoverian Series (6—7) in the Oslo Region is characterized by *Beyrichia* (*Eobeyrichia*), *Platybolbina*, and *Primitiella?* species, and *Craspedobolbina armata* sp.n. Only one genus, *Platybolbina*, is common with the rather rich beyrichiacean fauna of the late Upper Ordovician in the Oslo region (cf. HENNINGSMOEN, 1954). The Wenlock Series (8—9b) contains remarkably few berichiacean ostracods; only two genera, *Beyrichia* and *Apatobolbina*, are represented. This is rather strange, as the lithology is much the same as in the Llandoverian and Ludlovian beds, consisting mainly of shales and limestones. *Apatobolbina platygaster* has been found through all of

Known distribution of Silurian Beyrichiacea in the Oslo Region	Llandovery						Wenlock						Ludlow				
	6a	6b	6c	7a	7b	7c	8a	8b	8c	8d	9a	9b	9c	9d	9e	9f	9g
Beyrichia paucituberculata	.	S	OH														
Beyrichia zygophora	.	.	O														
Beyrichia osloensis	.	.	.	.	O	O											
Beyrichia skienensis	.	.	.	S													
Beyrichia cf. kloedeni	.	.	.	.	.	.	.	R	OR	OR	OR	OHR	HR	HR	R	R	R
Beyrichia kloedeni bicuspis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R
Beyrichia kiaeri	.	.	.	.	.	.	.	R	.	.	.	.	H				
Beyrichia ringerikensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?R	R
Beyrichia cf. jonesii	.	.	.	.	.	.	.	.	.	.	.	.	.	H			
Craspedobolbina armata	.	SHa	OH	.	O	.											
Craspedobolbina dorsoplicata	.	.	.	.	.	.	.	.	.	.	.	.	H	HR			
Craspedobolbina expansinodata	.	.	.	.	.	.	.	.	.	.	.	.	OR	R	.	R	R
Craspedobolbina primitiva	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	R	R
Apatobolbina platygaster	.	.	.	.	.	.	R	R	O	R	O	R					
Platybolbina tiara densistriata	.	.	O														
Platybolbina lunulifera	.	.	.	.	.	.	.	.	.	.	.	.	R	R	.	.	R
Platybolbina ? bulbosa	.	.	.	H	O												
Primitiella ? cf. parallela	.	S	O														
Primitiella ? bipunctata	.	.	OH														
Halliella ? seminulum	.	.	.	.	.	.	.	.	.	.	.	.	HR	.	.	.	R
Parabolbina diensti	.	.	.	.	.	.	.	.	.	.	.	.	.	H	.	.	.
Primitiopsis cf. planifrons	.	.	.	.	.	.	.	.	.	.	.	.	HR	HR	.	R	R
Primitiopsis dorsoplicata	.	.	.	.	.	.	.	.	.	.	.	.	HR	.	.	R	R
Signetopsis quadrilobata	.	.	.	.	.	.	.	.	.	.	.	.	H				
Signetopsis semicircularis	.	.	.	.	.	.	.	.	.	.	.	.	OR	HR	.	R	R
Signetopsis malornata	.	.	.	.	.	.	.	.	.	.	.	.	HR	.	.	.	R

O = Oslo-Asker area, H = Holmestrand area, S = Skien-Langesund area, R = Ringerike, Ha = Hadeland.

the Wenlock , but not below or above it, and may be a useful guide fossil for this series in the Oslo region. The beds assigned to the Ludlow Series (9c—9g) are very rich in beyrichiacean ostracods. Species of *Primitiopsis* and *Signetopsis* gen.n. seem to be especially characteristic of this series in the Oslo region, where they have not so far been found in older beds. *Beyrichia* and *Craspedobolbina* species are, however, at least as common. The rather characteristic *Beyrichia* (*Neobeyrichia*) *ringerikensis* sp.n. has only been found in 9g (and possibly in 9f), and may be a guide fossil for the uppermost part of the marine Ludlow Series in the Oslo region. This species seems to point towards the subgenus *Nodibeyrichia* which is known from the marine Downtonian in other countries.

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PLATES 1—8

All specimens were whitened before being photographed.

As a rule the light comes from the upper left corner, but there are few exceptions, either because the position of the fossil in the rock prevented his, or to bring better out certain details.

The photographs were taken by Faculty Photographer, Miss B. Mauritz.

The numbers in brackets in the explanations of the figures are the cataogue numbers of the specimens at the Paleontological Museum in Oslo.

PLATE 1.

Background blackened, otherwise not retouched.

Beyrichia (*Eobeyrichia*) *paucituberculata* sp.n. ....p. 37
6b, Gunneklev, Porsgrunn, Coll. J. Kiær 1902.
Fig. 1. x 12. *Holotype.* Left valve with pouch (50821a).
Fig. 2. x 13. Left valve with pouch (50822).
Fig. 3. x 11. Right valve (50821b). L2 broken.

Beyrichia (*Eobeyrichia*) *zygophora* sp.n. ....p. 38
6c *β*, Slependen, Asker. Coll. J. Kiær 1907.
Fig. 4. x 10. Left valve (53297b).
Fig. 5. x 12. Right valve with pouch (53297c). Anterior end broken.
Fig. 6. x 12. *Holotype.* Left valve (53297a).
Fig. 7. x 10. Right valve (53297d). L1 broken.
Fig. 8. x 11. Left valve (53297e). L2 broken.
Fig. 9. x 12. Right valve (53300a).

Beyrichia (*Eobeyrichia*) *osloensis* sp.n. ....p. 39
Fig. 10. x 12. Right valve (42840a). — 7b *β*, Ulvøya, Oslo. Coll. J. Kiær 1904.
Fig. 11. x 12. *Holotype.* Left valve (42940). — Hor. & loc. as fig. 10.
Fig. 12. x 12. Right valve with pouch (42856). — Hor. & loc. as fig. 10.
Fig. 13. x 12. Right valve with pouch (43304). — 7b *β*, Malmøya, Oslo. Coll. J. Kiær.
Fig. 14. x 12. Left valve (42840b). — Hor. & loc. as fig. 10.

Beyrichia (*Eobeyrichia*) *skienensis* sp.n. ....p. 39
7a, Klammer'n, Skien. Coll. J. Kiær 1902.
Fig. 15. x 11. Left valve (51060).
Fig. 16. x 11. *Holotype.* Left valve (51061).

PLATE 1

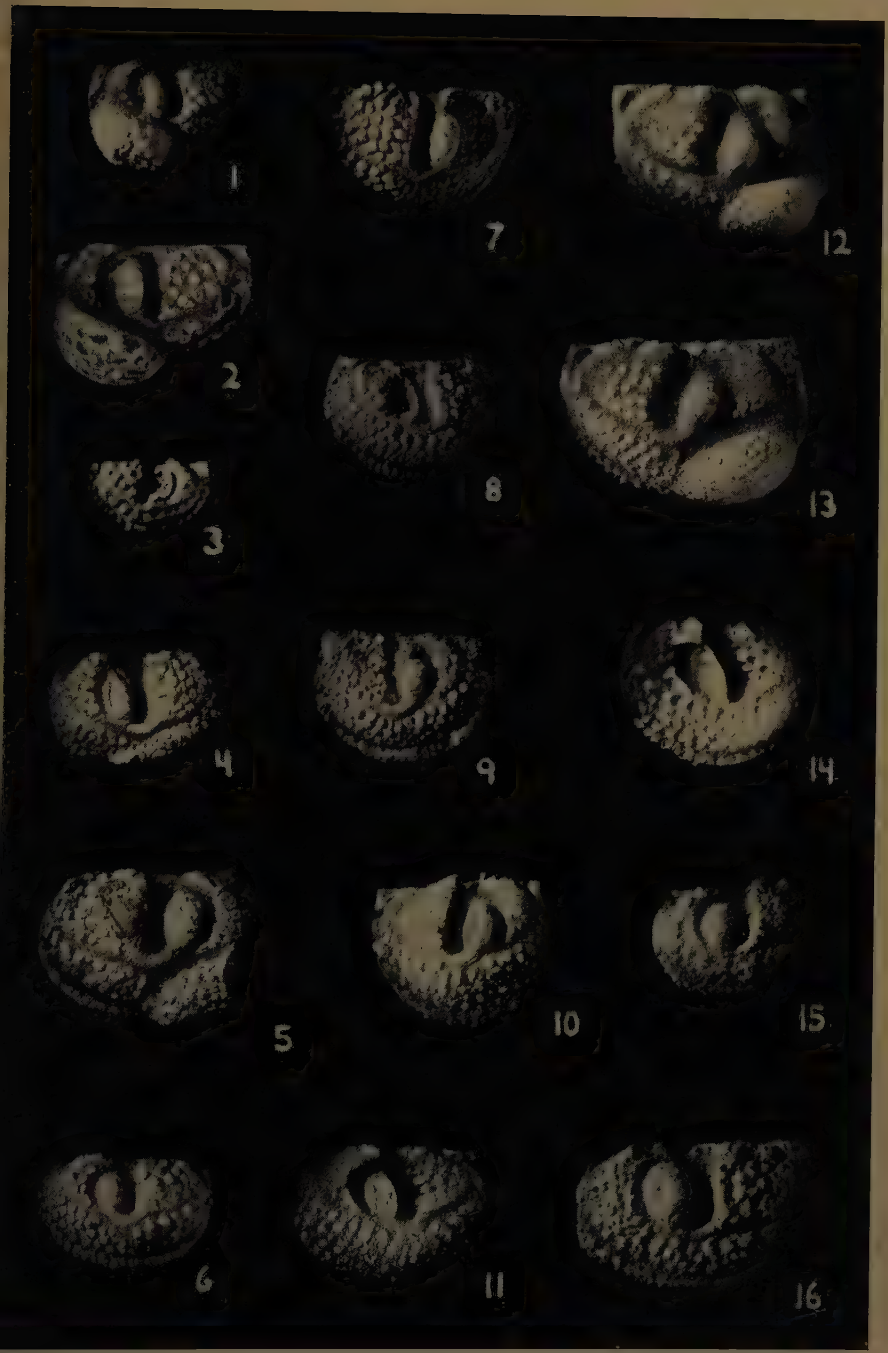


PLATE 2.

Background blackened, otherwise unretouched.

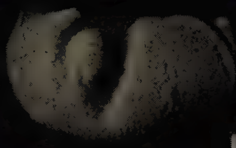
Beyrichia (*Beyrichia*) cf. *kloedeni* McCoy 1846 .... p. 40
8d, Storøy, Ringerike. Coll. J. Kiær 1912.
Fig. 1. x 11. Internal mould of left valve (47698).
Fig. 2. x 11. Left valve (48255), showing well the fissus.
Fig. 3. x 12. Left valve with exfoliated pouch (47697).

9a, Geitøy, Ringerike. Coll. J. Kiær 1903 .... p. 41
Fig. 4. x 11. Right valve with pouch (21846d).
Fig. 5. x 11. Left valve (21846a) with warthy «knee».
Fig. 6. x 18. Left valve with pouch (21846e).
Fig. 7. x 19. Right valve with pouch (21846b).
Fig. 8. x 11. Left valve with pouch (21846f).
Fig. 9. x 16. Left valve (21846c).

9a—b, Geitøy, Ringerike. Coll. J. Kiær 1911 .... p. 41
Fig. 10. x 11. Left valve (48222a).
Fig. 11. x 11. Left valve (48222b) with faint granulation.
Fig. 12. x 11. Left valve with pouch (48222c).

9b, Geitøy, Ringerike. Coll. J. Kiær 1931 (figs. 14, 18) and 1912 (the others). .... p. 41
Fig. 13. x 11. Left valve (48509a) with faint granulation dorsally.
Fig. 14. x 11. Left valve (66440a) with faint granulation dorsally.
Fig. 15. x 11. Left valve (48511a).
Fig. 16. x 11. Left valve (48511b) with faint «knee».
Fig. 17. x 11. Right valve (48509b) with warthy «knee».
Fig. 18. x 11. Right valve with pouch (66440b).

PLATE 2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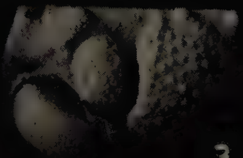
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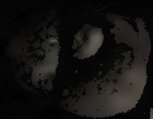
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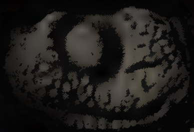
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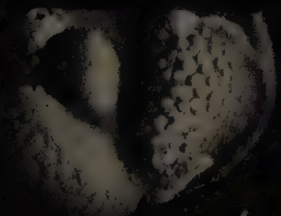
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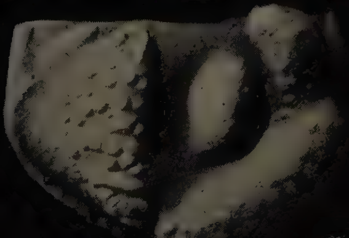
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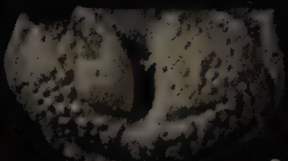
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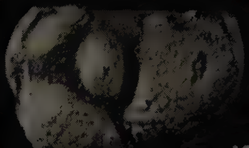
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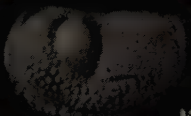
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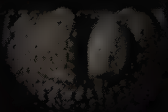
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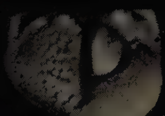
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PLATE 3.

Background blackened, otherwise not retouched.

Beyrichia (*Beyrichia*) cf. *kloedeni* McCoy 1846.
9c, Langøya, Holmestrand. Coll. Th. Kjerulf ....p. 42
Fig. 1. x 12. Right valve (49674). Long form. (= ? *Beyrichia* cf. *spinigera*.)

9c *β*, Skjørvold, Ringerike. Coll. J. Kiær 1906 (fig. 2) and 1905 (figs. 3, 4) ....p. 41
Fig. 2. x 11. Right valve (48665).
Fig. 3. x 11. Right valve (21874a).
Fig. 4. x 11. Right valve (21874b). Short form.

9d, Herøy, Ringrike. Coll. J. Kiær 1915 ....p. 42
Fig. 5. x 11. Left valve (48060a).
Fig. 6. x 11. Left valve (48060b) with very faint ornamentation.
Fig. 7. x 11. Left valve (48060c).

Beyrichia (*Beyrichia*) *kloedeni bicuspis* Kiesow 1888 ....p. 43
9g, Rudstangen, Ringerike. Coll. J. Kiær 1912 (fig. 8) and 1909 (figs. 9, 10).
Fig. 8. x 12. Right valve (66441a).
Fig. 9. x 12. Left valve (49104a).
Fig. 10. x 12. Right valve (49104b). Long form.

Beyrichia (*Mitrobeyrichia*) cf. *jonesii* Boll 1856 ....p. 46
9d, Langøya, Holmestrand. Coll. J. Kiær.
Fig. 11. x 12. Right valve (50426a).
Fig. 12. x 11. Left valve (50426b).

Beyrichia (*Beyrichia*) *kiaeri* sp.n. ....p. 43
Fig. 13. x 12. *Holotype*. Left valve (S 2789). — 9c *β*, Langøya, Holmestrand. Coll. L. Størmer.
Fig. 14. x 12. Left valve with pouch (46559b). — 8b, Bragsøy, Ringerike. Coll. J. Kiær 1912.
Fig. 15. x 12. Right valve (66449a). — Hor. & loc. as fig. 14.

Beyrichia (*Neobeyrichia*) *ringerikensis* sp.n. ....p. 44
Fig. 16. x 12. Right valve (49104c). — 9g, Rudstangen, Ringerike, Coll. J. Kiær 1909.
Fig. 17. x 11. Right valve (H 2753). Badly preserved, but showing well the pouch. 9g, Rudstangen, Ringerike. Coll. J. Kiær 1930.
Fig. 18. x 12. Left valve (49104d). — Hor. & loc. as fig. 16.
Fig. 19. x 13.5. *Holotype*. Right valve (48659). — 9g, Road section Kroksund-Vik. Coll. J. Kiær 1903.
Fig. 20. x 12. Left valve (66442a). — 9g, Rudstangen, Ringerike. Coll. J. Kiær 1912.
Fig. 21. x 13.5. Right valve (48723). — 9g, Rudstangen, Ringerike. Coll. J. Kiær 1903.

Plate 3

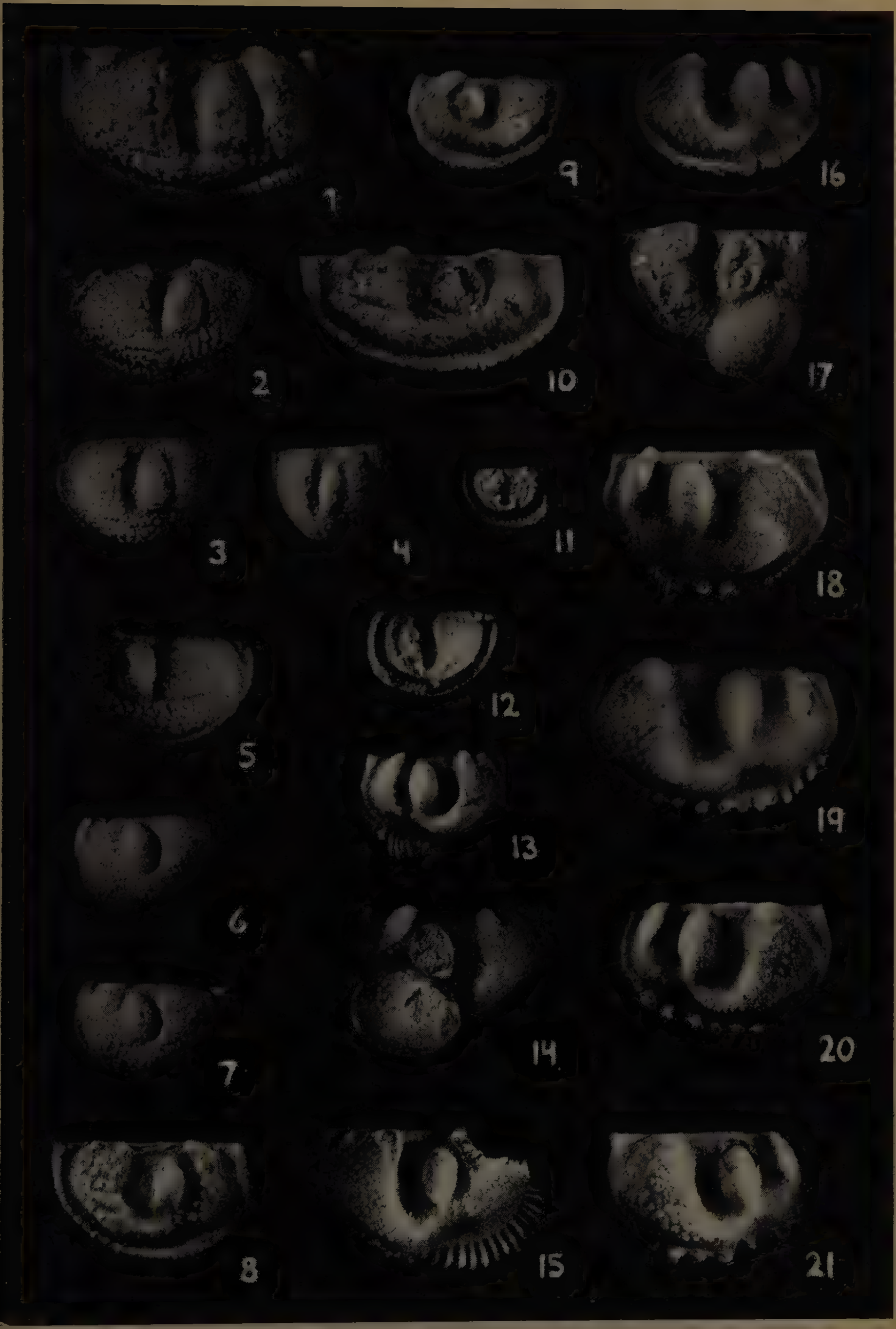


PLATE 4.

Craspedobolbina armata sp.n. ....p. 47

Fig. 1. x 12. *Holotype*. Right valve with pouch (52974a) — 6c β, Slependen st., Asker. Coll. J. Kiær 1906
Fig. 2. x 12. Right valve with pouch (52974b) — Hor. & loc. as fig. 1.
Fig. 3. x 12. Left valve with entire frill (66450) — 6c γ, Bjerkøya, Holmestrand. Coll. J. Kiær 1906.
Fig. 4. x 18. Left valve with restricted frill (52974c). — Hor. & loc. as fig. 1.

Craspedobolbina dorsoplicata sp.n. ....p. 48

Fig. 5. x 18. Right larval valve (S 2791f) — 9c β, Langøya, Holmestrand. Coll. L. Størmer 1918.
Fig. 6. x 18. Right valve with pouch (49676a). — 9d, Langøya, Holmestrand. Coll. W. C. Brøgger 1896.
Fig. 7. x 18. Left valve showing subsulcal node (49675b). — Hor. & loc. as fig. 5.
Fig. 8. x 18. *Holotype*. Left valve with pouch (49675a). — Hor. & loc. as fig. 5.

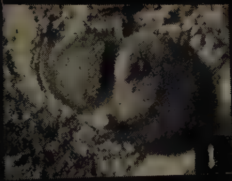
Craspedobolbina expansinodata sp.n. ....p. 49

Fig. 9. x 18. Right valve with pouch (48710a). — 9c, Utøy, Ringerike. Coll. J. Kiær 1901.
Fig. 10. x 18. Right valve (48710c). — Hor. & loc. as fig. 9.
Fig. 11. x 18. Right valve (48710d). — Hor. & loc. as fig. 9.
Fig. 12. x 18. Left valve (48710e). — Hor. & loc. as fig. 9.
Fig. 13. x 12.5. *Holotype* (48710f). Left valve with pouch, showing well the ornamentation. — Hor. & loc. as fig. 9.
Fig. 14. x 18. Right valve (48710b). — Hor. & loc. as fig. 9.
Fig. 15. x 21. Right valve (49104). — 9g, Rudstangen, Ringerike. Coll. J. Kiær 1909.
Fig. 16. x 18. Left valve (49195). — 9g, Rudstangen, Ringerike. Coll. J. Kiær 1912.
Fig. 17. x 18. Right valve with pouch (49196). — Hor. & loc. as fig. 16.

Craspedobolbina primitiva (Verworn 1887)...................p. 50

Fig. 18. x 20. Left valve (66441c). — 9g, Rudstangen, Ringerike. Coll. J. Kiær 1912.
Fig. 19. x 20. Right valve (66441b). — Hor. & loc. as fig. 18.

PLATE 4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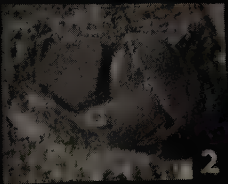
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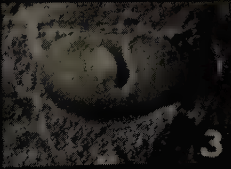
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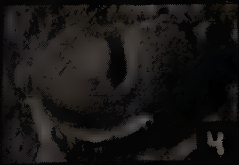
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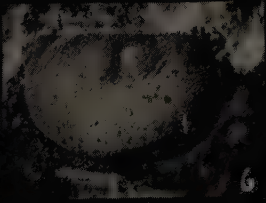
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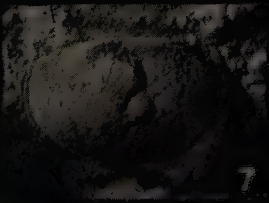
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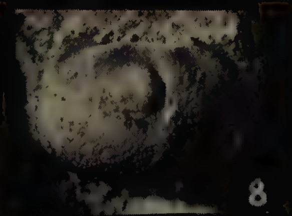
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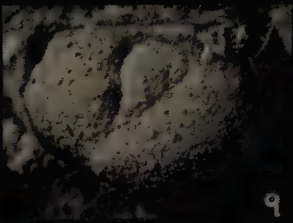
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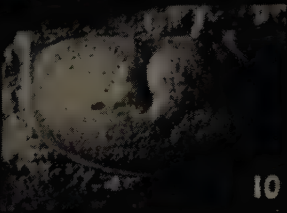
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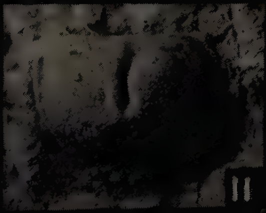
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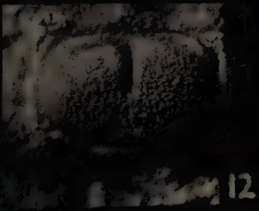
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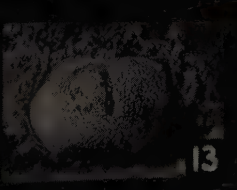
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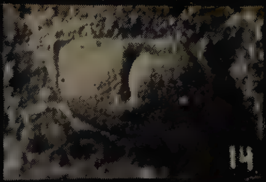
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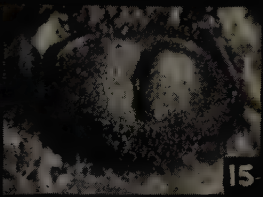
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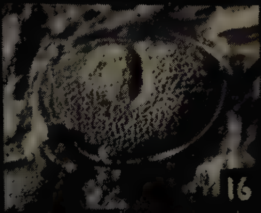
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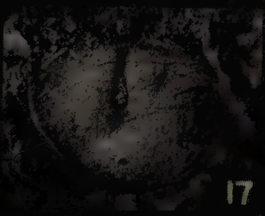
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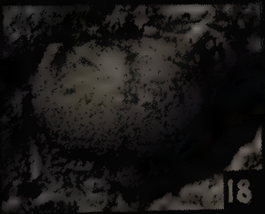
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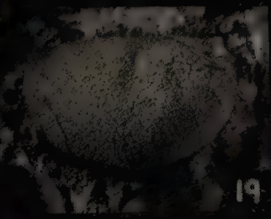
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PLATE 5.

Craspedobolbina dorsoplicata sp.n. ....p. 48

Figs. 1—3. x 12.5. Ventral view (anterior end up), dorsal view (anterior end up), and lateral view of right side of entire carapace (49676a). — 9d, Langøya, Holmestrand. Coll. W. C. Brøgger 1896.

Craspedobolbina primitiva (Verworn 1887) ....p. 50

Fig. 4. x 20. Right valve with pouch (66442b). — 9g, Rudstangen, Ringerike. Coll. J. Kiær 1912.

Fig. 5. x 20. Left valve with pouch (66444a).) — Hor. & loc. as fig. 4.

Fig. 6. x 20. Right valve (H 2760). — 9g, Rudstangen, Ringerike. Coll. J. Kiær 1930.

Fig. 7. x 20. Right valve (66444 b). — Hor. & loc. as fig. 4.

Apatobolbina platygaster (Kummreow 1924)..................p. 51

Fig. 8. x 12. Right valve (46559d) with well preserved frill. — 8b, Bragsøy, Ringerike. Coll. J. Kiær 1912.

Fig. 9. x 12. Right valve (47483) with broken frill. — 8d, Sønsterud, Ringerike. Coll. J. Kiær 1910.

Fig. 10. x 12. Left valve with pouch (66449c). Frill partly broken off. — Hor. & loc. as fig. 8.

Fig. 11. x 12. Left valve with pouch (66449d). Frill broken off. — Hor. & loc. as fig. 8.

Fig. 12. x 12. Left valve (46559c) with partly broken frill. — Hor. & loc. as fig. 8.

Fig. 13. x 12. Ventral view of same valve as in fig. 12.

Platybolbina tiara densistriata subsp.n.......................p. 53

Fig. 14. x 11. *Holotype.* External impression of right valve (53314). — 6c β, Løkkåsen, Sandvika, Bærum. Coll. J. Kiær 1907.

Fig. 15. x 11. Left valve (66454). — 6c β, Malmøya, Oslo. Coll. G. Henningsmoen 1953.

Platybolbina? bulbosa sp.n. ....p. 54

7b β, Ulvøya, Oslo. Coll. J. Kiær 1904.

Fig. 16. x 20. Right valve (42945a).

Fig. 17. x 20. Right valve (42945b).

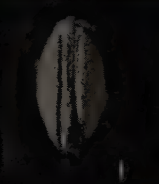
Fig. 18. x 20. Right valve (42945c).

Fig. 19. x 20. Right valve (42945d).

Fig. 20. x 20. *Holotype.* Right valve (42945e).

Fig. 21. x 20. Right valve (42946) showing well the surface ornamentation.

PLATE 5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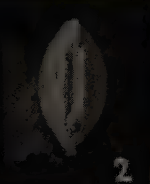
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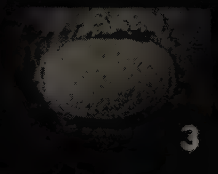
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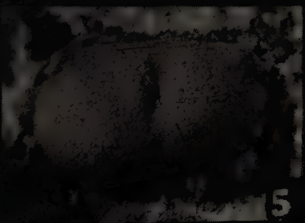
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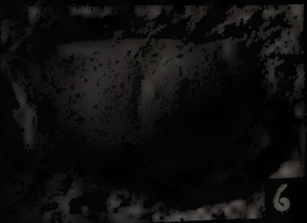
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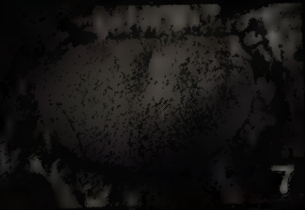
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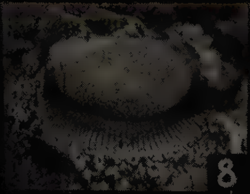
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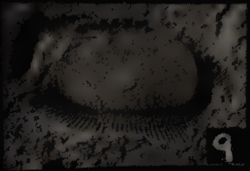
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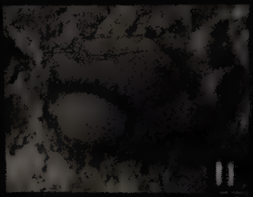
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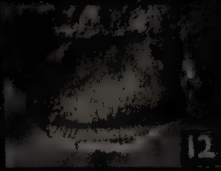
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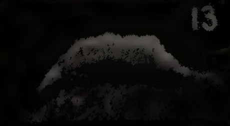
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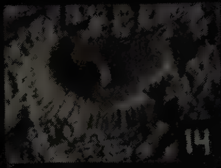
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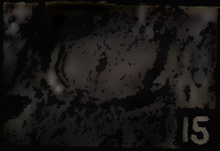
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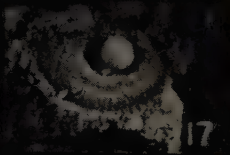
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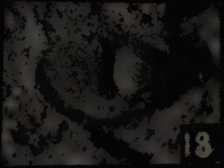
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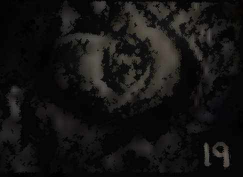
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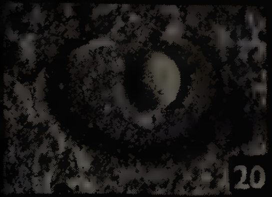
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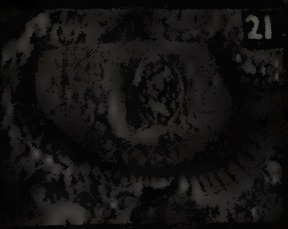
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PLATE 6.

Platybolbina lunulifera sp.n. ....p. 53
9d, Herøy, Ringerike. Coll. J. Kiær 1912.
Fig. 1. x 20. Valve with narrow frill (48062a).
Fig. 2. x 17. Valve with narrow frill (48062b).
Fig. 3. x 20. Valve with wide frill (48062c).
Fig. 4. x 17. *Holotype.* Valve with wide frill (48062d).

Parabolbina diensti (Kummerow 1924) ....p. 58
9d, Langøya, Holmestrand. Coll. J. Kiær.
Fig. 5. x 13. Right valve with scalloped frill (50426).
Fig. 6. x 36. Small left valve (50503). Larval form of this species?

Primitiella? bipunctata sp.n. ....p. 56
Fig. 7. x 20. *Holotype.* Right valve (53300b). — 6c β, Slependen, Asker. Coll. J. Kiær 1907.
Fig. 8. x 20. Right valve (53297f). — Hor. & loc. as fig. 7.
Fig. 11. x 12. Left valve (66451). Partly weathered and showing internal structure of shell. — 6c β, Bjerkøya, Holmestrand. Coll. J. Kiær 1907.

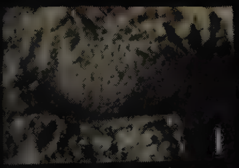
Primitiella? cf. *parallela* (Kummerow 1924) ....p. 55
6b, Gunneklev, Porsgrunn. Coll. J. Kiær 1902.
Fig. 9. x 20. Left valve (50821e).
Fig. 10. x 20. Left valve (50821d).

Halliella? seminulum (Jones 1855) ....p. 57
Fig. 12. x 17. Right valve (66441b). — 9g, Rudstangen, Ringerike. Coll. J. Kiær 1912.

Primitiopsis dorsoplicata sp.n. ....p. 61
9g, Road section Kroksund-Vik, Ringerike. Coll. J. Kiær 1903.
Fig. 13. x 20. *Holotype.* Right valve (48635a) with wide posterior frill.
Fig. 14. x 20. Right valve (48633) without posterior frill.
Fig. 15. x 21. Right valve (48635b) with wide posterior frill.

Primitiopsis cf. *planifrons* Jones 1887 ....p. 60
Fig. 16. x 19. Right valve without posterior frill (49136a). — 9g, Road section Kroksund-Vik, Ringerike. Coll. J. Kiær 1903.
Fig. 17. x 18. Left valve without frill (50438a). — 9g, Langøya, Holmestrand. Coll. J. Kiær 1901.
Fig. 18. x 19. Right valve with posterior frill (50438b). — Hor. & loc. as fig. 17.
Fig. 19. x 22. Internal mould of right valve with posterior frill (50438c). — Hor. & loc. as fig. 17.

PLATE 6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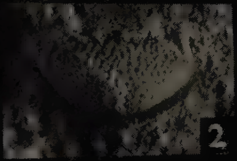
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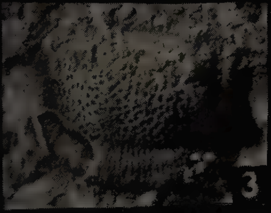
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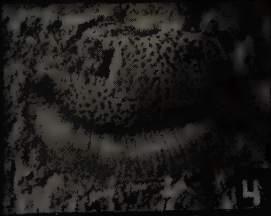
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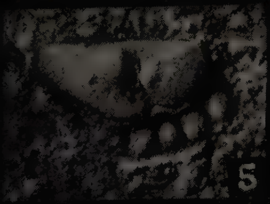
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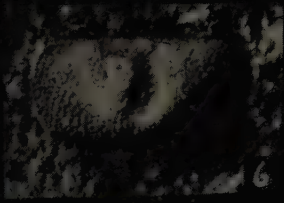
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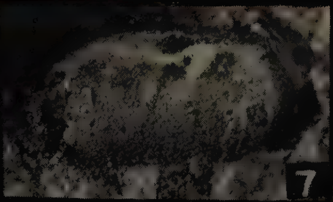
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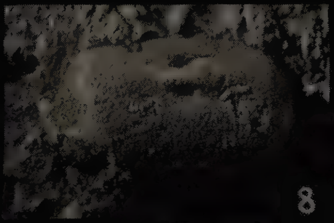
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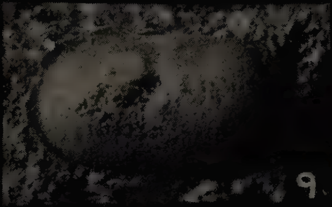
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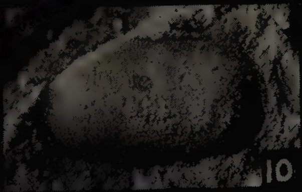
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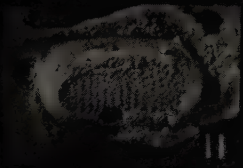
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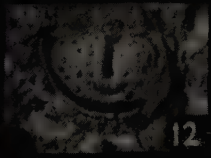
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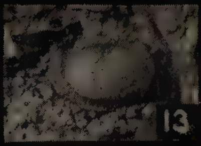
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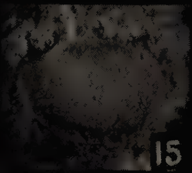
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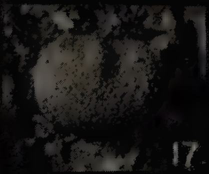
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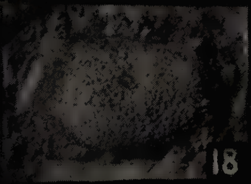
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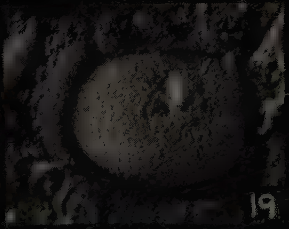
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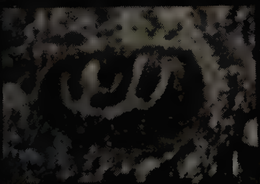
PLATE 7.

Signetopsis quadrilobata sp.n. .... p. 61
9c *β*, Langøya, Holmestrand. Coll. L. Størmer 1918.
Fig. 1. x 35. *Holotype*. Left valve (S 2791d).
Fig. 2. x 35. Right valve (S 2791p).
Fig. 3. x 35. Left valve (S 2791n).
Fig. 4. x 35. Right valve (S 2791k).
Fig. 5. x 35. Left valve (S 2791s) with wide posterior frill.
Fig. 6. x 35. Left valve (S 2791m).
Fig. 7. x 35. Right valve (S 2791b).
Fig. 8. x 35. Left valve (S 2791r).
Fig. 9. x 35. Left valve (S 2791j) with wide posterior frill.

Signetopsis semicircularis (Krause 1891) .... p. 61
Fig. 10. x 22. Right valve (49137a). — 9g, Road section Kroksund-Vik, Ringerike. Coll. J. Kiær 1903.
Fig. 11. x 20. Right valve (49137b). — Hor. & loc. as fig. 10.
Fig. 12. x 21. Left valve (49137c) with wide posterior frill. — Hor. & loc. as fig. 10.
Fig. 13. x 20. Right valve (49104e). — 9g, Rudstangen, Ringerike. Coll. J. Kiær 1909.
Fig. 14. x 21. Left valve (49128). — Hor. & loc. as fig. 10.
Fig. 15. x 21. Left valve (49131) agreeing well with «*S. rotundata*». — Hor. & loc. as fig. 10.
Fig. 16. x 23. Quadrilobate left valve (49129) probably belonging to *S. semicircularis*. — Hor. & loc. as fig. 10.

Signetopsis malornata sp.n. .... p. 64
Fig. 17. x 35. Left valve (S 2791g). — 9c *β*, Langøya, Holmestrand. Coll. L. Størmer 1918.
Fig. 18. x 35. *Holotype*. Left valve (S 2791m). — Hor. & loc. as fig. 17.
Fig. 19. x 22. Right valve (49119a) and left valve (49119b). — 9g, Rudstangen, Ringerike. Coll. J. Kiær 1909.
Fig. 20. x 22. Left valve (49119c) with wide posterior frill. — Hor. & loc. as fig. 19.
Fig. 21. x 22. Right valve (49119d) (not internal mould!) without ventral velate structure. — Hor. & loc. as fig. 19.
Fig. 22. x 22. Right valve (49119e) with wide posterior frill. — Lobation unusually well developed. — Hor. & loc. as fig. 19.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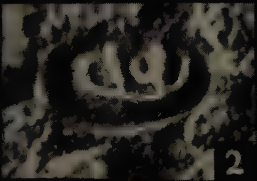
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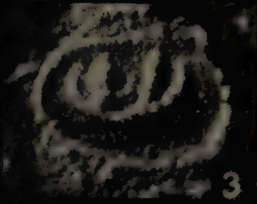
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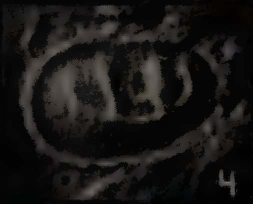
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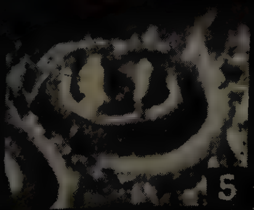
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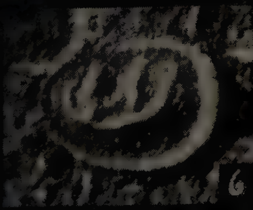
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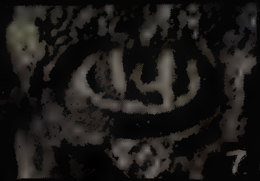
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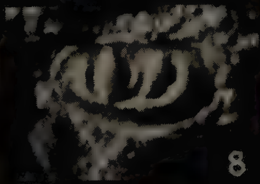
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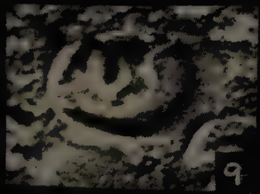
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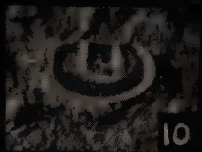
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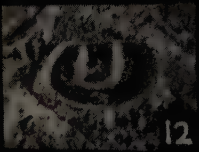
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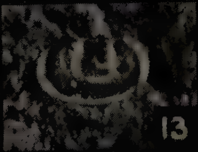
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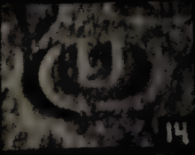
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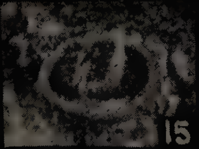
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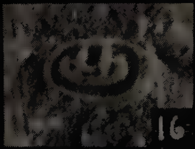
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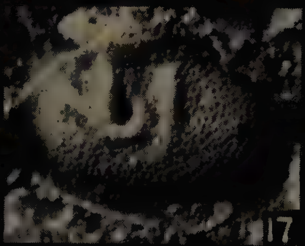
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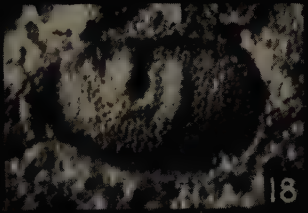
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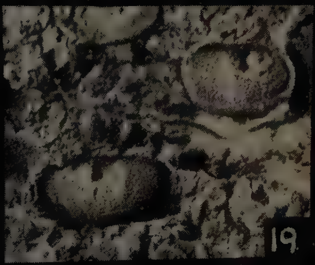
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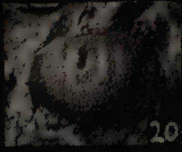
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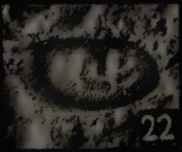
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PLATE 8.

Reconstructions of left valves. Surface ornamentation somewhat schematic.

Figs. 1—9 (*Beyrichia* species) approximately x 9.

Figs. 10—30 approximately x 15.

Fig. 1.	*Beyrichia* (*Eobeyrichia*) *paucituberculata* sp.n.	p. 37
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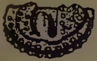
Fig. 29.	*Primitiopsis dorsoplicata* sp.n.	p. 61
Fig. 30.	*Parabolbina diensti* (Kummerow 1924)	p. 58

PLATE 8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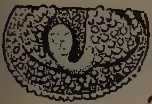
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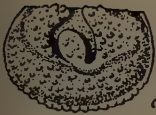
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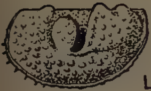
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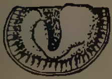
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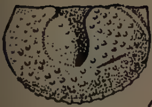
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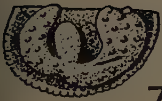
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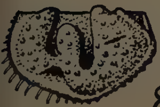
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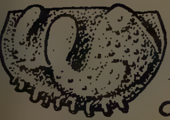
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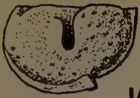
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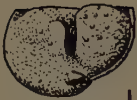
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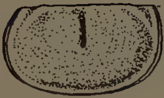
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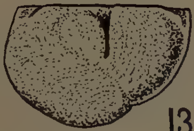
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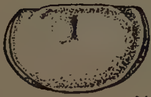
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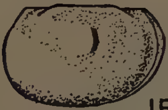
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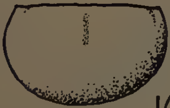
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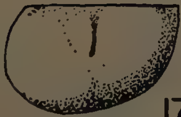
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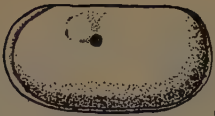
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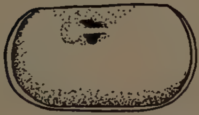
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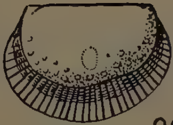
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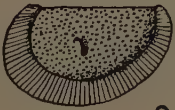
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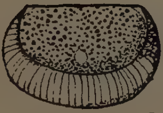
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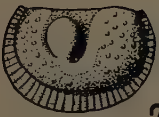
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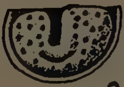
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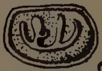
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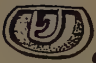
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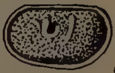
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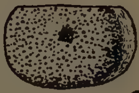
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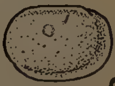
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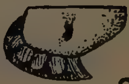
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THE MAMMOTH TEETH FROM NORWAY

BY

A. HEINTZ

Abstract. Two new mammoth-mollars from Norway are described: one left upper M_2 from Vågå, and one fragment of a lower M_2 from Ula. The new investigation of the earlier described teeth shows that the teeth from Skarvangen (Vågå) and Dovre are not Dp_4 as previously assumed, but M_1, and the tooth from Otta is probably a M_3.

The Scandinavian teeth most probably belong to sub.sp. *Mammonteus primigenius primigenius* Osborn.

The question of when the mammoth lived in Norway is discussed, and it is presumed, that the mammoths had their haunts in the high mountains of Scandinavia and that they lived here in great numbers during the last interglacial period. Finally the distribution of the musk-ox, reindeer and horse in Scandinavia during the last interglacial period is discussed.

Introduction.

The remains of mammoth (*Mammonteus primigenius* BLUMENBACH) are very rare in the Scandinavian peninsula. Up to now no more than 12 finds from Sweden and 7 from Norway have been described. The first Norwegian find was made in 1886, the last in 1944. All our finds are more or less well preserved teeth, and all of them have been found in central Norway. Five are grinding teeth, two are fragments of the tusks. Three grinding teeth and one tusk were fully described by BERGERSEN in 1932. The second tusk was described by HEINTZ in 1945. One of the last two grinding teeth was mentioned in 1932 and 1951, and the other preliminarily described by HEINTZ in 1951.

The description of the two last discovered grinding teeth.

THE TOOTH FROM VÅGÅ

(*P.M.O. 66483, Fig. 1. Pl. I*).

This tooth was discovered in 1933 by chauffeur TORBJØRN BØJE not far from the farm «Sandbu nordre» on the riverbank where the river Finna runs into the river Otta. BØJE was walking along the river, waiting for his lorry to be loaded with sand, when he caught sight of a queer stone among the pebbles, on the bank, which in springtime is flooded. He picked it up, washed it and thought it reminded him of a large tooth. BØJE showed the «stone» to the veterinary HOFSTAD in Vågå, who said, that it undoubtedly, was a tooth of a prehistoric animal.

The tooth was sent to the Zoological Museum in Oslo, where the headcurator, WOLLEBÆCK gave it to Professor BERGERSEN for description. Unfortunately Professor BERGERSEN did not have time to finish the investigation, and after the war he kindly delivered the tooth, and two drawings, prepared under his direction, to me for description. I hereby wish to express my best thanks to Professor BERGERSEN for his courtesy.

The tooth from Vågå (Pl. I) represents a more or less strongly worn front part of a middle-sized mammoth tooth. The grinding surface (crown) (Pl. I, C) is 91.5 mm long and 62.3 mm in the broadest part (between the 6th and 7th enamel ridges). The tooth has been broader, as the cement originally covering both sides of the tooth has completely disappeared and the enamel ridges are also so much worn that the dentine in the ridges on both sides is visible (Fig. 1, Pl. I, A, B, d, e). Thus it is reasonable to suppose that the tooth was at least 8 to 10 mm broader, which means that the whole tooth was about 70—72 mm broad. It is highest at the back where it is broken and here measures 75 mm.

The grinding surface of the tooth is convex and its right side is more worn than the left side, indicating that the tooth is a fragment of *the upper left molar*.

Seven distinct enamel ridges are visible on the grinding surface

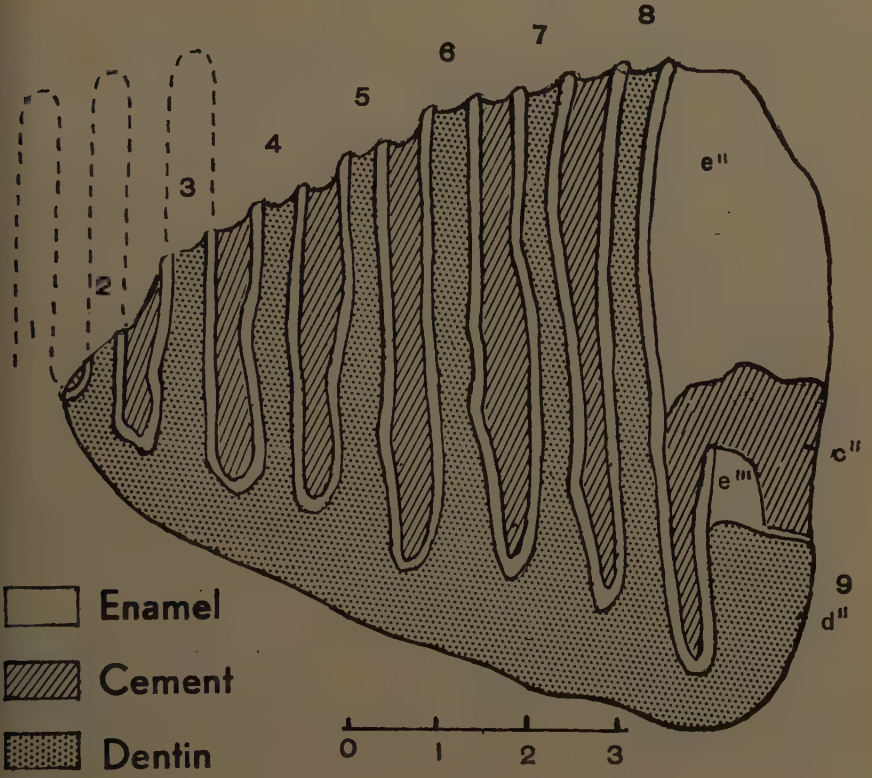

Fig. 1. Diagrammatic picture of the mammoth-tooth from Vågå, seen from the right. The probable position of the enamel ridges which are worn away is indicated. 1 to 9 — emamel ridges.

(Pl. I, C). The remains of two more ridges can also be seen — one mainly in front, and the other mainly behind.

The front ridge is practically invisible, but its existence seems apparent if one studies the fragment of the enamel ridge preserved mainly in the front of the tooth (Fig. 1, Pl. I, A, B, x; C, c', e'). This enamel fragment consists of a small oval slightly concave plate of about 16 mm's length and 10 mm's width, covered in the middle part with a thin sheet of cement (Fig. 1, Pl. I, C, e', c'). Its concave form and the presence of cement indicate that what we have here is not the frontal enamel lamelle, but the bottom of an enamel fold between two enamel ridges (Fig. 1, 1—2). Accordingly we must expect that at least one more enamel ridge was originally developed in front of the first, now clearly visible ridge.

At the back the tooth is broken between the 8th and 9th enamel ridges. One can here see the bottom of the 8th enamel fold (Fig. 1, 8—9. Pl. I, A, B, 8). The hind surface of the tooth in the upper part consists of the enamel layer forming the posterior limit of the 8th enamel ridge (Fig. 1, Pl. I, A, B, e''). Further down one can see some of the cement (Fig. 1, Pl. I, A, B, c'') placed between the 8th and 9th ridges. Still further down the enamel layer, forming the front of the 9th ridge, is visible (e'''). Finally, at the very bottom of the surface the dentine from the middle part of the 9th ridge is preserved. (Fig. 1, Pl. I, A, B, d'').

No traces of the roots are visible. The lower surface of the tooth is smooth and only below the 8th enamel ridge a slight impression can be seen. As is known, the anterior root in the mammoth teeth is as a rule strongly developed. I have noticed that it is only in the case of some large molars (M_2 and M_3) that we find that the roots are almost completely absorbed in the front part of the tooth. It is, however, impossible to determine with certainty whether the roots in our specimen are absorbed or worn away during transportation. I think, however, that the last supposition is the most probable.

We shall now try to determine if the tooth we are dealing with belongs to the premolars (Dp) or to the molars (M). The first and second premolars (Dp_2 and Dp_3 of the mammoth are so small and have so few dentine ridges (4 resp. 8) that we can immediately see that the tooth in question cannot belong to this group. The last molar (M_3) on the other hand, is so big and has such a great number of ridges (from 18 to 27) that it is quite out of the question that our tooth was M_3. Finally we have the last premolar (Dp_4) and the two first molars. According to SOERGEL (1912) the ridge formula of these teeth are:

$Dp_4 \frac{9—12,}{9—12,}$ $M_1 \frac{9—15,}{9—15,}$ $M_2 \frac{12—18,}{12—18,}$. OSBORN, however, gives another formula, he calls it «typical» and it is as follows:

$$Dp_4 \frac{12,}{12,} \quad M_1 \frac{12,}{12,} \quad M_2 \frac{16.}{16,}$$

As mentioned above the tooth we are dealing with has 9 ridges. As it is not a complete tooth but only a fragment, it is difficult to determine with certainty how many dentine ridges have been broken off. The broadest part of a mammoth tooth is generally placed somewhat in front of the middle of the tooth. As the broadest part of this particular tooth, measured between the 6th and 7th enamel ridge, is 70 mm from the front, one may assume that the total length of the tooth was about 150—160 mm. In the preserved part of the tooth one ridge and a cement layer is about 10 mm broad. It is therefore reasonable to suppose that this tooth originally had about 15—16 dentine ridges. According to the above mentioned ridge formula, the tooth can thus be either the first or the second molar (M_1 or M_2).

This interpretation, based only on the number of ridges is confirmed when we measure the width of the tooth. As already mentioned its maximum breadth is now about 63 mm as the tooth is strongly worn on both sides. Originally it must have been at least 67—70 mm.

Measurements of the length and breadth of a number of mammoth teeth are given in papers by PAVLOVA (1910) and ZALENSKY (1903). The breadth of M_1 varies from 42 to 85 mm, with an average of 65 (15 teeth). The breadth of M_2 varies from 60 to 88 mm, with an average of 76 mm (12 teeth). On the other hand the breadth of Dp_4 is remarkably smaller and varies from 39 to 54 mm, with an average of 45 mm (5 teeth).

It is obvious that the tooth according to its breadth must either be M_1 or M_2. However, it corresponds better with M_2 both as to the number of enamel ridges (ca. 15—16) and length (ca. 150—160) and breadth (ca. 70—72 mm). As is known M_2 has from 12 to 18 enamel ridges and is averagely 151 mm long and 76 mm broad.

Thus one can conclude with comparatively great certainty that the second mammoth tooth discovered in Vågå in 1933 is a fragment of a *left upper* M_2 and has belonged to a fully grown animal.

THE TOOTH FROM ULA

(P.M.O. 66484, Pl. II, A, B,)

The tooth from Ula was discovered by Agent GUNNAR MOEN in 1944, the same man who found the mammoth tooth in Otta in 1910—

1911. He discovered the tooth on a fishing trip along the river Ula, about 2 kilometers from the place where Ula runs into Lågen (Gudbrandsdalen). The tooth, a relatively small fragment, lay among some large stones on the bank of the river which is flooded in the spring, and it is sure to have been transported by the river for a considerable distance.

As mentioned above the Ula-tooth represents only a small fragment of a tooth. Originally it was strongly rolled, but became damaged when Moen picked it up. The original, strongly rolled surface, can only be seen from one side, the other sides are broken (Pl. II, B). The fragment, however, does not seem to have been much larger. It consists of two well preserved enamel ridges (Pl. II, A, B, II, III), a small fragment of the third (I), and in the worn surface a bit of the fourth (IV) ridge can be seen. The height of the fragment is 99 mm, the maximum breadth 70 mm and the length only 30 mm. The grinding surface is slightly concave, indicating that the tooth is a lower molar. At the bottom of the tooth a clear and deep impression marks the presence of a strongly absorbed or erroded root (Pl. II, B, a).

Of all the measurements mentioned, only the breadth can give us some information about the position of the tooth in the dentination.

As mentioned above, the maximum breadth is about 70 mm. It was probably somewhat broader higher up, near the grinding surface. The tooth is strongly worn on the sides, showing that the breadth originally must have been at least 72—75 mm, probably more, indicating that we here have a fragment of a M_2tooth. The mammoth tooth from Ula is therefore most probably *the lower second molar* (M_2).

Some remarks about the earlier known mammoth-teeth from Norway.

THE TOOTH FROM SKARVANGEN (VÅGÅ)

(*P.M.O. 66478 Pl. II, C*).

According to Bergersen (1932, pg. 381—84) the tooth from Skarvangen (Vågå), most probably consists of 12 enamel ridges and one isolated denticle right at the back. Bergersen discussed the development of the enamel ridges in the front part of the tooth, and mentioned that the distance between the front limit of the tooth and the first enamel stripe seen («ersten sichtbaren Schmelsstreifen») (Pl. II, C, b) is about 15 mm. He supposed that this distance was too big, compared with the condition known in other teeth, and pointed out, that in front of the first observable enamel stripe (b) one can see a small triangular-shaped spot (Pl. II, C, a), which indicates the presence of an enamel ridge, now completely worn off. BERGERSEN does not give any other description of the development of the enamel figures on the surface of this tooth, but refers to COLLETT (1911—12). Translated to English COLLETT's description is as follows (COLLETT, 1911—12 p. 725—26).

«Enamel stripes form 10 elongated, separate ovals (besides 2 rudiments in the posterior part). Of these the first one is developed only on one (out) side and is completely closed (Comp. Pl. II, C, b). The others are also complete with the exception of the 5th, which is represented by *a single enamel stripe only.*» (Italicized here, Comp. Pl. II, C, x—x).

The description is in fact very remarkable. If one remembers the structure of the mammoth-tooth and the arrangement of the enamel ridges, it must be obvious that the presence of a «single enamel stripe» is quite impossible. This clearly shows, that COLLETT has misunderstood the enamel figures in the front part of the tooth. His first «oval» (Pl. II, C. b) represents, in fact, *not* an enamel *ridge*, but the bottom of an *enamel fold between* two ridges (Pl. II, C 2—3). As the tooth is strongly worn here, the chewing-surface has reached the limit between the crown and the root, accordingly the *bottom* of the enamel fold. One can therefore conclude, that the minute triangular-shaped spot (Pl. II, C, a) mentioned by BERGERSEN is not the last trace of an enamel ridge, but an enamel fold between two ridges (Pl. II, C, 1—2). (BERGERSEN (1932, p. 398) described the corresponding condition in the front part of the tooth from Dovre). This new interpretation of the development of the enamel ridges in the tooth from Skarvangen, does not change BERGERSEN's determination of the number of enamel ridges in the tooth we are dealing with. There are at least 12 of them, besides one denticle. If we regard this denticle as a minute ridge — it shows that the Skarvangen-tooth has 13 ridges. In Pl. II, C one can see the surface of the tooth, with the enamel ridges numbered from 1 to 12 in the correct way. The dentical in the posterior part is not visible.

As BERGERSEN points out, the number of the dentine ridges corresponds well with the number known from Dp_4, that is from 9 to 12. The number of the ridges in M_1, however, is almost similar — from 9 to 15 (OSBORN mentioned 12). It is therefore impossible to determine, by means of the enamel ridges only, whether the tooth from Vågå is Dp_4 or a M_1.

However, if we also take the dimensions of the tooth into consideration, the picture becomes much clearer. According to PAVLOVA (1910) and ZALENSKY (1903) the Dp_4 teeth are very small. The 5 specimens they have measured vary in length from 82 to 110 mm (averagely 93 mm) and in breadth from 39 to 54 mm (averagely 45 mm). As mentioned above, the M_1, however, had an average length of 131 mm and the breadth was 65 mm. As the tooth from Skarvangen is 139 mm long and 66 mm broad it is more probable that it is the first molar (M,), and not, as BERGERSEN presumed, the last premolar (Dp_4).

THE TOOTH FROM DOVRE (*P.M.O. 66481*).

This tooth (BERGERSEN 1932, p. 395—400) shows only 6 ridges. According to BERGERSEN, however, the tooth is strongly worn and its posterior part is broken off. He therefore meant that there was reason to believe that it has consisted of 10 to 12 ridges. BERGERSEN assumes that we also here have a Dp_4 tooth.

But again the dimensions of the tooth are too big. The length is 110 mm (according to BERGERSEN 115 mm) and the maximum breadth at least 63 mm, probably more. As the front part of the tooth is chewed down and the back of it has been broken off, it has obviously been at least 120—130 mm long. Thus it is most probable that also the Dovre tooth is a M_1, and not Dp_4 as BERGERSEN presumes.

THE TOOTH FROM OTTA (*P.M.O. 66479*).

The tooth from Otta (BERGERSEN 1932, p. 386—90) is strongly erroded and badly preserved. Only five ridges can be seen. BERGERSEN (1932) assumes that it has belonged to a fully grown animal.

The maximum breadth of the largest ridge is 80 mm (according to Bergersen 78 mm). As the cement has completely disappeared, the maximum breadth has originally been greater, probably not less than 88 mm. This corresponds well with the breadth of the last molars: M_3 (averagely 86 mm and min. 80 mm). The tooth from Otta therefore most probably is M_3.

In the conclusion of his paper (p. 400) Bergersen says: «Die beiden genannten Zähne (Vågå and Dovre) haben also ganz jungen Tieren gehört.... Man findet nicht häufig fossile Reste eines derartigen Jugendstadiums, ... Leider erlauben indessen die Fundumstände keine weitere Schlussvolgerungen in Bezug auf das Auftreten und Aussterben des Mammutes in unserem Lande.» As we have seen, this conclusion is not absolutely correct. None of our mammoth teeth belong to especially young animals, and at least 5 (both tusks and the teeth from Otta, Ula and the second from Vågå) certainly come from adult or old animals.

Subspecies of *Mammonteus primigenius* (BLUMENBACH) and the Norwegian mammoth-teeth.

In the posthumous volume II of Osborn's monography on Proboscidea (1942) eight different «subspecies»* of *Mammonteus primigenius* are more or less completely described. Osborn has also attempted to reconstruct the main changes during the evolution of the species *M. primigenius* from «Lower Pleistocene to Postglacial time». In other Proboscidea the evolutionary changes can also be found in a more complicated development of the grinding teeth. The number of the enamel ridges increases, while the breadth of the single ridges decreases. According to Osborn the same tendency can be observed in *M. primigenius*, which can be seen from the short description of the molars in the different subspecies (Osborn, 1942).

1) *Mammonteus primigenius astensis* (Depéret & Mayet) is the oldest known subspecies of mammoth and, according to Depéret & Mayet (1923), belongs to the Upper Pliocene deposits in North Italy.

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* In many places in the Monography the word «species» is incorrectly used instead of the word «subspecies». Comp. pp. 1137, 1140, 1150, 1156, 1159 a.o.

OSBORN, however, mentioned that it is more probable that the deposits are from Lower Pleistocene. The two last molars (M_3) which have been found have only 19 and 20 comparatively broad enamel ridges. The ridge-plate compression is 8 in 100 mm.

2) *Mammonteus primigenius leith-adamsi* (POHLIG). This is a diminutive variety of mammoth, determined by POHLIG (1888) as belonging to the III-d (?) Interglacial. It was found in Thuringia, Germany. OSBORN, however, doubts that this form really belongs to *M. primigenius* — phyllum, as the molars are a bit too long and narrow and the ridges are too far apart. According to OSBORN (pp. 1140) there are 19—20. The ridge-plate compression is not determined.

3) *Mammonteus primigenius hydruntinus* (BOTTI). This is a dwarfed race from the cavern of Cardanone, South Italy (BOTTI, 1891). Only one M_1 and one Dp_4 have been found. Both have 12 ridges. The length of M_1 is about 122 mm, and accordingly it has 10 ridges in 100 mm. The geological age is not certain.

4) *Mammonteus primigenius fraasi* (DIETRICH). This very large subspecies is based on a complete skeleton discovered in 1910 in Steinheim a. d. Murr, Germany, and described by DIETRICH (1912). It belongs to «Mitteldiluvialen Schottern». OSBORN, however, determined the age as III—d (?) Interglacial (p. 1138) and «Middle (Upper ?) Pleistocene» (p. 1152). The M_3 has 22 ridges and is 270 mm long. The ridge-plate compression then, is 8 in 100 mm.

5) *Mammonteus primigenius primigenius* OSBORN. OSBORN is not quite consistent and clear when he establishes this subspecies. He only used the term *M. primigenius primigenius* in a few places (1942, pp. 1140, 1143) and instead used the term *M. primigenius*, «typical *M. primigenius*» (pp. 1143, 1144, 1149, 1150 a. o.) or «true *M. primigenius*« (pp. 1143, 1144, 1145 a. o.). One cannot find the concise definition of this new subspecies, as the description given on pp. 1141—1149 concerns *species Mammonteus primigenius* (BLUMENBACH, 1799, 1803). From this description, however, we get a clear picture of what OSBORN meant by subspecies *M. primigenius primigenius*. According to OSBORN this subspecies belonged, to the «Upper Pleistocene drift (IV Glacial) and Postglacial deposits of the Fourth Glaciation» and is widely spread over Europe, Siberia and N. America.

Among the characteristic features of this is the more or less constant ridge-formula of the grinding-teeth enamel ridges. The M_3 has 24 ridges. The ridge-plate compressions are 10 to 12 (normally 10) in 100 mm.

6) *Mammonteus primigenius americanus* (DE KAY). This subspecies is based on some molar teeth from Rochester, N.Y. (DE KAY 1942). The type specimen has, however, been destroyed by fire. According to OSBORN, the M_3 consists of $\frac{26}{24}$ ridges. The ridge-plate compression is 10+ ridges in 100 mm. This subspecies seems rather problematic and a reexamination based on new and better material will be necessary.

7) *Mammonteus primigenius alaskensis* OSBORN. This subspecies* is based on a series of crania, discovered in 1929 in Fairbank, Alaska (FRICK, 1933) and preliminarily described by OSBORN in 1942. The average number of ridges in M_3 is 25. The ridge-plate compression is not mentioned.

8) *Mammonteus primigenius compressus* OSBORN. This subspecies is based on skeleton remains from Indiana and Alaska (OSBORN 1924) and is probably from the Postglacial or retreat period, IV Glacial (Wisconsin). The number of ridges in M_3 is $\frac{27}{27}$ and the ridge-plate compression is unusually great — 13 in 100 mm.

Besides these eight subspecies, at least two others have been proposed by other authors. In 1845 BLAINVILLE mentioned two new subspecies *Elephas primigenius sibiricus* and *Elephas primigenius germanicus*. In 1923 DEPÉRET & MAYET accepted the name *Elephas primigenius sibiricus* and regarded it as a variety of minute size. Also TOLMACHOFF (1939) mentioned «a special race» from N. Siberia, «distinguishable.... by its smaller size» (p. 44).

OSBORN, however, believed that these two forms «perhaps may be regarded as geographic designations rather than as subspecies» (1942, p. 1391).

It seems, however, that the subspecies errected by OSBORN are more or less indefinable and cannot be used without a revision of the whole material. In fact PAVLOVA (1906) described a large M_3 from the New Siberian Islands — consequently a typical *M. primigenius primigenius* OSBORN — with 27 ridges and a ridge compression of only 9 in 100 mm. However, she mentioned that some teeth in the collection of Moscow University show «much smaller ridges with thinner enamel . . . . » and therefore must have had higher ridge compressions. PFIZENMAYER (1926) mentioned that the molar teeth of mammoth from Siberia consist of «zahlreiche (bis achtundzwanzig, mitunter dreizig) . . . . Schmelzscheiben» (p. 238). In another paper PAVLOVA (1910) published a table of the ridge-plate compression in various specimens of mammoth, both from South Russia and Siberia. The table shows that the compression *varies* strongly in spite of the fact that all these specimens must belong to OSBORN's «typical» *M. primigenius primigenius*. The lowest number of compressions is 7, and the highest — 12. The most common, however, is 10.

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* Incorrectly called «sp.nov.» in OSBORN 1942, p. 1159.

Returning to the Norwegian grinding teeth, we must state that they do not belong to any of the first four of OSBORN's «subspecies». They have all the same ridge-plate compression — that is 9 to 10 in 100 mm, and thus correspond well with OSBORN's «subspecies *M. primigenius primigenius*». The assumed number of the ridges in the single teeth (where it was possible to determine them) also corresponds well with the «typical» formula proposed by OSBORN. Thus we have every reason to presume that the mammoth-teeth we are dealing with belonged to a form which, in structure of teeth, corresponds to the most common form of mammoth, known from Europe, Asia and N. America.

In his monography OSBORN (1942) does not go into detail as to the *geological age* of the «subspecies» of *M. primigenius primigenius*. In many places, however, he mentions that this subspecies belongs to «Upper Pleistocene (IV Glaciation) and postglacial deposits» (pp. 1137, 1138, 1140, 1141, 1150). If his supposition is correct, however, the Scandinavian mammoth-teeth must either belong to the *postglacial period*, or in fact be the *oldest known* representatives of the «true *M. primigenius*». As we shall see later (p. 99) both these assumptions are very improbable.

In the literature on *M. primigenius*, however, the most common statement is that «typical *M. primigenius*» is known (in all cases from

N. Europe) both from the III and IV Glaciation. SOERGEL discussed the origin (1912) and the distribution (1941) of the mammoth in Eurasia. In the first paper he emphasized that *Elephas primigenius* had developed from *E. trogontherii* at the end of the Mindel-Riss interglacial, and according to this is known as early as from Riss (III) Glaciation. In the second paper he mentioned that the typical mammoth is known «in Mittel- und Jungdiluvium — vom Risseiszeit komplex an» (p. 32). «Ueberal findet sich das Mammut in Mitteleuropa. . . in Schottern und Lössen sowohl des Würmeiszeitkomplexes als des Risseiszeitkomplexes» (p. 32). In handbooks of historical geology and palaeontology the distribution of the mammoth is always assigned to the III and IV Glaciation (ZITTEL, ABEL, KEISER, ROEMER, ARKANGELSKIJ a.o.).

As we have seen, OSBORN only mentioned two «subspecies» of *Mammonteus primigenius* from the III Glaciation (Riss) which differ more or less distincly from *M. primigenius primigenius.* — They are *M. p. leith-adamsi*, which was a «diminutive variety» and *M. p. fraasi* — a very large form, both known only from a single specimen of each. The specimens of *M. primigenius* mentioned by other authors from the deposits of III Glaciation, cannot be identical with these two subspecies.

Consequently OSBORN's determination of «typical mammoth» as a form only known from IV (Würm) Glaciation, cannot in any case be the correct as to Europe. However, no uncertain find of typical mammoth from III Glaciation has to my knowledge been reported from N. America.

The fragments of mammoth from Scandinavia clearly indicate that the mammoth in Middle Europe must have lived during the Riss Glaciation. Strangely enough the mammoth finds from Sweden, Finland and Norway are *not mentioned* by OSBORN, and on his distribution-maps of *M. primigenius*, Scandinavia, Finland and the northern part of European Russia are not coloured black (fig. 1028 and 1241). TOLMACHOFF (1929), however, mentioned that «east of the White Sea, in the basin of the Pechora River» the fragments of typical mammoth «are just as numerous as in corresponding parts of Western Siberia. West of the White Sea and of the Lakes Onega and Ladoga, remnants of the mammoth are rare». As to the occurrence of mammoth in Scandinavia, TOLMACHOFF referred to LEYL's paper from 1887 (!) and mentioned that «Scandinavia.... probably even lacked the mammoth. The rare specimens of mammoth bones found there were, in LEYL's opinion, brought there by ice or otherwise». In the paper of OBERMAIER (1924), however, there is a map of the distribution of Mammoth in Europe. On this map the northern limit is drawn correctly through Finland and Scandinavia.

When did the mammoth live in Norway ?

In my paper about the mammoth from Fåvang (HEINTZ, 1945) I dealt with the question of when the mammoth lived in Norway. I came to the conclusion, that the opinion expressed by most earlier authors (BJØRLYKKE, 1941, BRØGGER, 1914, COLLETT, 1911, 12, HOLTEDAHL, 1931, 40, 42, 53, RAMSAY, 1931, REUSCH, 1910 a. o.) that the mammoth lived in Norway during the last interglacial period, is correct.

P. GEIJER and O. KULLING (1945) and later R. SANDEGREN (1950) are of the same opinion as to the mammoth-fragments discovered in Sweden.

As mentioned above mammoth-teeth and bone-fragments have been found in Sweden at 12 different localities (Fig. 2) (SANDEGREN 1950). They are represented by 8 grinding teeth, 6 fragments of tusks and about 10 fragments of bones (Pilgrimstad). Of these finds only one has been found in its original position, below the ground moraine of the last glaciation in deposits from the last interglacial period. According to the investigation of KULLING (1945) in Pilgrimstad the «varying amounts of water in the glacifluvial streams caused the deposits.... to fluctuate between varved clay and coarse, stony gravels. In the varved clay were embedded remains of the vegetation covering the country between the inland ice and the place of deposition.... The arctic plant remains preserved in the varved clay were mainly leaves of *Dryas octopetala*, fragments of *Salices* were less frequent and such of *Betula nana* exceptional. During a somewhat later stage gravel and sand were deposited by running water. In the sand, ...there were embedded remains of the animals then living in the region, such as mammoth and reindeer» (p. 60).

As one can see, these deposits must belong to the early part of the last interglacial period, when the condition, in this part of Sweden were still arctic. All the other mammoth-finds in Sweden are from secondary positions, but two of them, according to SANDEGREN (1950) are undoubtedly from the interglacial deposits. They are the find from Dösebacka (ALIN & SANDEGREN 1947, SANDEGREN 1950) and that from Ramsele (SANDEGREN 1950). Five of the finds were made in the most southern part of Sweden — in Skåne (Fig. 2, 13—16,)— and therefore naturally belong to the same geographical and geological region as the finds from Denmark.

The 78 mammoth-teeth and bone-fragments discovered in Denmark (NORDMANN 1905, 1925, 1942,) (Fig. 2) are all, with the exception of one, found in secondary position. The only fragment which undoubtedly lay in its original position in the deposits from the last interglacial time, is the pelvic-fragment from Ejstrup (NORDMANN 1921) (Fig. 2 A). It was discovered in deposits of spawn and humus-bearing sand with a rich temperate flora (*Picea excelsa, Carpinus betulus, Stratiotes aloides, Taxus baccata. Ilex aquifolium, Pinus silvestris* etc.) and fauna (*Bythinia leachii, Anodonta* sp. *Perca fluviatilis, Abramis brama, Esox lucius,* a piece of wood gnawn by *Castor fiber,* a cone gnawn by *Sciurus vulgaris,* fragments of bone of *Cervus dama*).

However, NORDMANN pointed out that the pelvic of *Elephas primigenius* and *Elephas antiquus* are very alike, and in addition show strong individual variations. It is therefore impossible to determine the discovered fragments with certainty. According to NORDMANN, however, the pelvic from Ejstrup most resembles the mammoth-pelvics from Bukovar and Borna, which he studied in Germany. This is the reason for NORDMANN concluding the description with the statement that «in the last Interglacial time there was an elephant living in Denmark, and this elephant probably was a mammoth» (p. 17, translated). GEIJER (1945), however, remarks that the temperate flora and fauna discovered together with elephant-fragments, make it more probable that we here have *Elephas antiquus* and not *Elephas primigenius,* especially if we take into consideration the fact that teeth of *E. antiquus* were later found in Denmark (NORDMANN 1930). I am of the same opinion, and I find it reasonable, to believe that the fragments from Ejstrup do not belong to *Mammonteus* (*Elephas*) *primigenius*.

The other 77 mammoth-fragments were all found in a secondary position. All, except 5, were found in glacial deposits inside the limit of the last glaciation (NORDMANN 1921, p. 7) (Fig. 2). This indicates that they belong to animals, living *before* the last glacial period. But NORDMANN meant that we cannot say when and where the animals have lived, except for the not very much enlightening fact that they lived inside the region from which the advancing last glaciation could remove them.

However, if we look at the map of Denmark and S. Sweden (Fig.2) we can clearly see, that the mammoth-finds are distinctly accumulated in the region of the end-moraine from the last glaciation. These have already been mentioned by NATHORST (1894) and AAGAARD (1896). Mammoth-fragments may therefore have been transported from many different localities at varying distances from Denmark and S. Sweden — probably from Norway, N. Sweden, Balticum etc.

As to the single finds from Denmark and S. Sweden, we must mention, that some of them are more or less strongly damaged, fractured, rolled and show distinct stripes — indications that they must have been transported varying distances by the ice. However, some finds are unusually well preserved, and do not show any kind of damage. I can here mention the grinding-teeth from Højballegaard, Sæbberup, Friedsted, Kollindsund, Hesselager, Glænø and Mogenstrup (AAGAARD 1896, NORDMANN 1921, 42), and especially the tooth from Snoghøj (DREYER JØRGENSEN 1940). In some cases bone and tooth-fragments, probably belonging to the same individual were found near to each other (Børup Sand, Kallerup, Nymølle(?) NORDMANN 1921, 42). In yet other cases comparatively fragile bones were more or less well preserved when they were found (fragments of vertebrates, Langaa and Børup Sand, NORDMANN 1921, 42). All these facts make it probable that they have not been exposed to a long transport, as already mentioned by DREYER JØRGENSEN (1940).

In any case it seems reasonable to presume that some of the mammoth-finds from S. Sweden and Denmark belong to animals, that have lived in the neighbourhood of the localities where the fragments have been found.

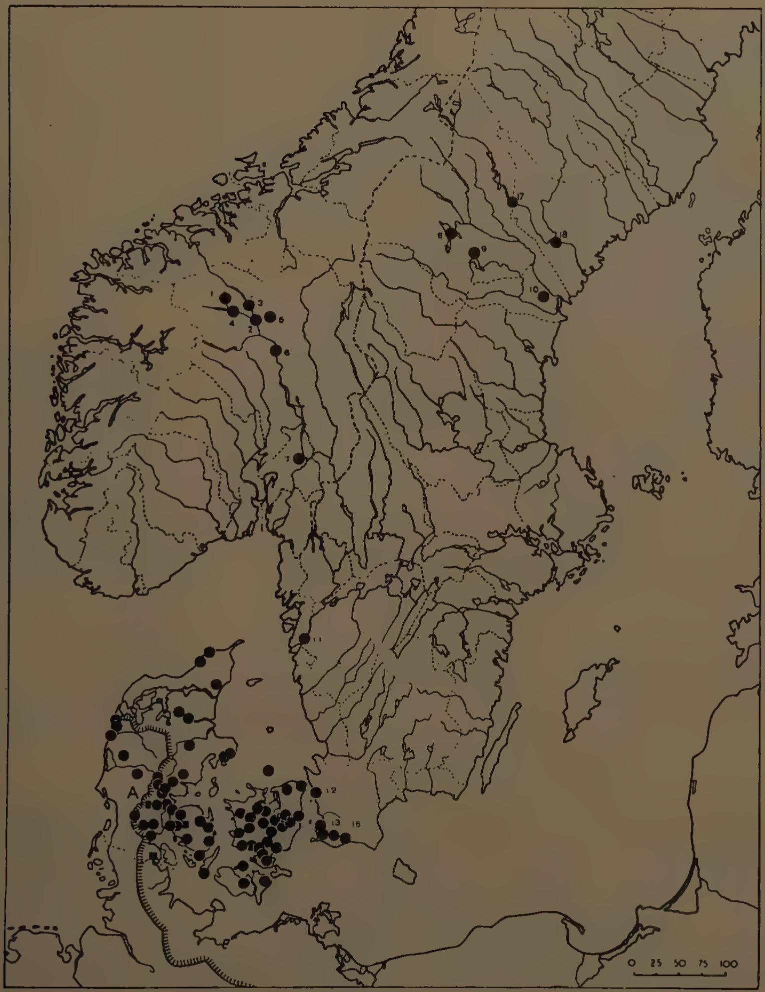

Fig. 2. Finds of mammoth-remains in Norway, Sweden and Denmark. Norwegian finds: 1- Skarvangen seter (Vågå), 2- Otta, 3- Dovre, 4- Vågå, 5- Ula, 6- Fåvang, 7- Jessheim. Swedish finds: 8- Fräsön, 9- Pilgrimstad, 10- Sättna, 11- Dösebacka, 12- Bårslöv, 13-16- Lockarop, Arrie, Svedala and Skurup. 17 - Ramsele, 18 - Sollefteå - Danish finds not numbered (compare Nordmann 1942). The limit of the last glaciation marked with IIIIIIIIII, the mammoth finds with ●, the *Elephas antiquus* find with ■. After SANDEGREN 1950 and NORDMANN 1942.

It is more difficult to answer the question of when the mammoth lived in these districts. The mammoth is a typical arctic animal. It lived in the tundras and on the steppes and normally not in the forests (Soergel 1941, Osborn 1942). During the Riss-Glaciation Denmark was completely covered with ice, and no animals could live there. The climate was definitely no colder during the last interglacial than it is now. Denmark and S. Sweden were covered by temperate, mostly deciduous forests (fossil plants from Ejstrup, Nordmann 1921). This fact makes it very improbable that the mammoth really belongs to the fauna of Denmark at that time, especially if we remember that *Elephas antiquus* and probably *E. trogontherium* lived in Denmark in the last interglacial (fossil from Ejstrup(?), Uglebjerg and Steinsigmose Strand. Nordmann 1942).

It therefore seems most reasonable to presume, that the mammoth lived in Denmark for only a comparatively short period. This should then be at the *beginning* of the *last interglacial* (Riss-Wurm), when the climate was still arctic, and the animals followed the retreating glaciers towards the north, and in the *beginning* of the *last glaciation*, when the climate became arctic, and the animals migrated southwards in front of the advancing glacier. We can probably regard the most weathered and damaged fragments from Denmark as belonging to the beginning of the last interglacial, and the best preserved as belonging to the beginning of the last glacial.

As mentioned above, 5 of the finds from Denmark, have been made *outside* the endmoraine of the last glaciation (in Vestjylland: Fjaltring Kirke, Bøvling Enge, Bjerghuse, Sædding and Sønder Omme). Nordmann (1942) means that this should indicate that they cannot be younger than from the second interglacial (Mindel-Riss), as Denmark was completely covered by ice during the Riss-glaciation. As far as I can see, however, none of these 5 finds have been made in the deposits from the second interglacial or the third glacial (Nordmann 1904, 21, 42; Aagaard 1896), although deposits of both these periods have been discovered in Vestjylland. The five teeth in question are no more weathered or damaged than many others that have been found in the eastern part of Denmark. I therefore find it very reasonable to believe that these teeth also belonged to animals that lived in the last interglacial, and not in the preceding one. The fact

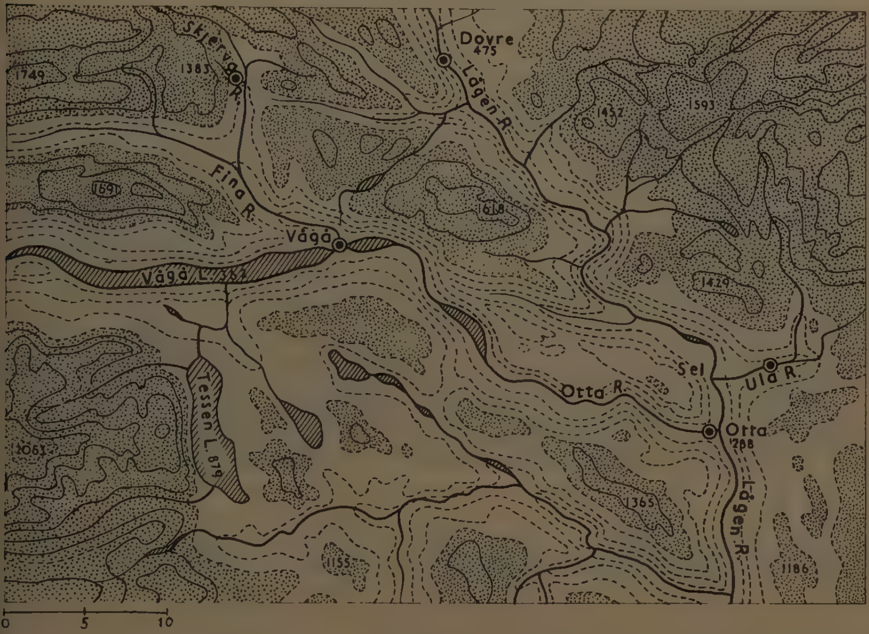

Fig. 3. Map showing the district of Central Norway, where the grinding-teeth of mammoth have been found. The localities are marked with ⊙ Equidistans — 200 m. The part above 1000 m is dotted. No railroads, roads or settlements are marked on the map.

that they were found outside the limit of the moraine from the last glaciation, must not be regarded as a proof against this supposition. Thousands of mammoth-teeth found in Poland, Germany, Russia etc. outside the end moraine of the last glaciation have undoubtedly belonged to animals that have lived partly in the last interglacial, partly in the last glacial periods.

If we now turn to the teeth from Norway, we see that the 5 grinding-teeth which have been found, have all been discovered in the same district in central Norway, that is Vågå—Otta—Dovre (Fig. 3). This district lies between the three greatest mountain-ranges in S. Norway: Jotunheimen (to the SW), Rondane (to the E) and Dovre (to the N). The teeth were found in, or by, streams and brooks.

Thanks to a scholarship from the Nansen Foundation, I had

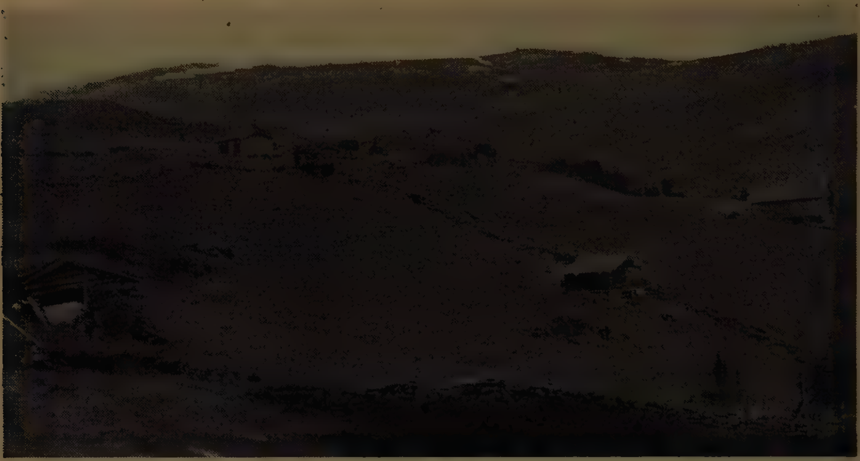

Fig. 4. General view to the north of Skarvangen seter-grend. Skarvangen seter — the house furthest to the left in the background. The River Skjerva runs in a deep valley behind the house furthest to the right in the foreground. Photo A. Heintz.

during the summer of 1952 the opportunity of visiting all the localities where the grinding-teeth have been found. In the whole district the glacial and fluvioglacial deposits are strongly developed. In many places the moraines and terraces caused by ice-dammed lakes are especially large.

The first tooth discovered in 1886, was found near Skarvangen seter (Fig. 4). It lay among boulders in a brook, which COLLETT (1911—12), ØYEN (1916), BERGERSEN (1932) and others called the «Milthaug»-brook. However, this name, cannot be found on newer maps. People living in Skarvangen seter (=chalet) do not know it either, but point out, that the tooth was found by Storbekk (= Large brook) which is between Skarvangen and Milthaugseter, and flows out into the river Skjerva. Skjerva-river is a tributary to the river Finna, which runs into the Vågå-lake. The Skarvangenseter lies about 926 m a. s. l. in a typical glacial landscape (Fig. 6). A marked terrace, caused by an ice-dammed lake, can be seen on both sides of Skjerva (Fig. 7). Typical «dead-ice» pits are also preserved here (Fig. 5). The landscape is comparatively open, except for the deep and narrow valley, where the river flows. The mountains around are not very high (about 1200—1500 m). The Skarvangen-tooth is very well preserved — the best preserved tooth which has been found in Norway. It is only slightly rolled, and the cement is practically not weathered at all. It is therefore very probable that it has not been exposed to a violent or long transportation, and that the animal it came from, died in the vicinity of the district where the tooth was discovered.

The second tooth from the Vågå-district (p. 74, Fig. 3, Pl. I) was found near the place where the river Finna flows into the Vågå-lake. It consequently belongs to the same river-system as the first Vågå-tooth, but was found about 12 km from Skarvangen and ca. 550 m lower down. It is comparatively well preserved, although it is strongly rolled. The cement is erroded from the sides and the back of the tooth is broken off. This clearly shows that it has been transported for a considerable distance.

The third tooth, belonging to the same river-system, is the first tooth from Otta (BERGERSEN 1932). It was found near the railway-station at Otta on an island in the river Otta, which comes from the Vågå-lake. This locality lies about 40 km from Skarvangen and about 610 m lower down. The tooth is very damaged and weathered indeed and represents only a few lamellae of a large tooth. From this we can tell that it has been carried a long way by the river, and that it has been subject to very rough transportation.

The two last Norwegian mammoth grinding-teeth were discovered in two other river-systems (Fig. 3). The second tooth from Otta (p. 77) was found in the lower part of the river Ula, which comes from the Rondane-mountains district. As mentioned above, it was a strongly rolled fragment of a tooth, which indicates a long transportation and strong wear (Pl. II, A, B). Not far from the place where the tooth was discovered, one can on the side of the river bed see a weathered white moraine, forming remarkable earth pillars, called «Kvitskriuprestinn» (= the white screw priests). In a paper published in 1943 (a) K. STRØM draws the conclusion, that this moraine «is older than the last glaciation, and thus has had a long enough time for sufficient consolidation during interglacial time and the last glaciation». STRØM mentioned as one trait, which seems to confirm his theory «that

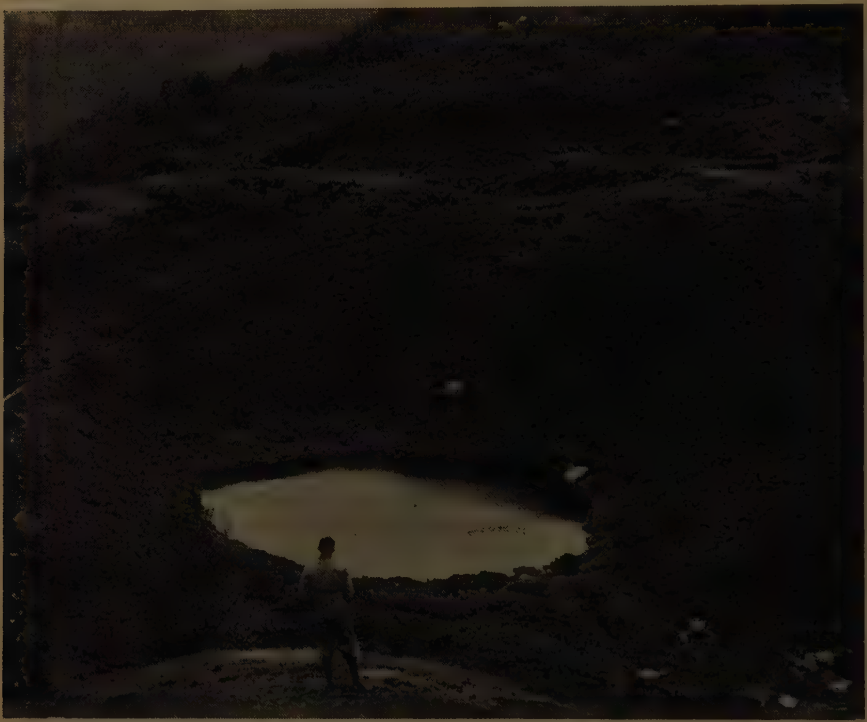

Fig. 5. The dead-ice pond in the typical glacial landscape between Skarvangen seter (in the background) and Storbekken-brook. Picture taken towards the south. Photo A. Heintz.

the Ottadal and Gudbrandsdal yield all the existing six finds of interglacial mammoth. These valleys have thus not been scoured clean of loose deposits, and there is every reason to believe that *at least* abundant material of moraines from the glaciation preceding the last is preserved» (1943, a). In another paper STRØM (1943, b) in addition mentioned that «during the last glaciation.... the movement of the glacier was moderately near the iceshed and in the deep valleys parts of the loose deposits with mammoth-teeth have avoided the transportation by the glaciers» (translated).

When STRØM published these papers, the tooth from Ula had not yet been discovered. This find can therefore be regarded as a corro-

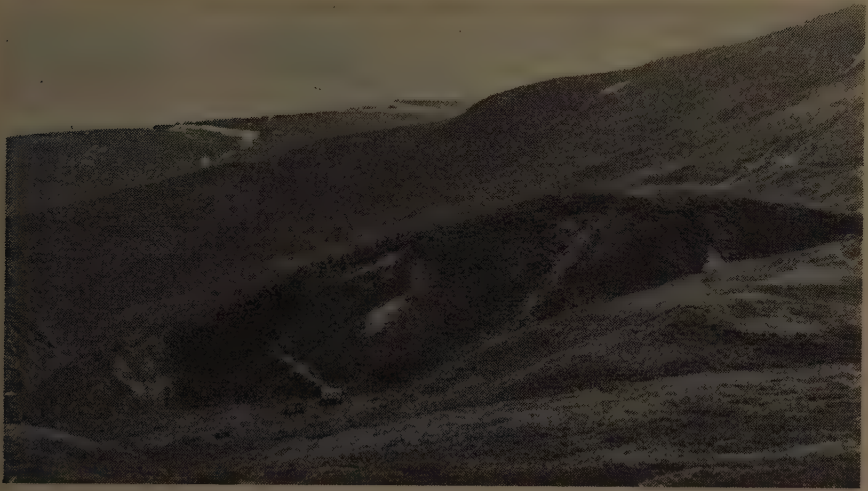

Fig. 6. The glacial deposits north of Skarvangen seter, cut through by Storbekken, which runs along the gravel and sand ridge, behind the houses in the middle of the picture. Photo A. Heintz.

boration of his theory, One must, however, remember, that it is very improbable, that the mammoth-tooth was preserved in the «Kvitskriuprestinn»-moraine if this moraine really is from the Riss-glaciation, as STRØM presumed. As a matter of fact this would indicate, that the mammoth has lived in Norway in Mindel-Riss interglacial, and that the tooth has «outlived» two glaciations!

The last grinding-tooth was found not far from Dovre railway-station (BERGERSEN 1932) on an island in Lågen — the river which runs through Gudbrandsdalen. It was comparatively well preserved and not rolled, but slightly weathered. The points of the roots and a small part of the back are missing. It seems to be the best preserved tooth, apart from the tooth from Skarvangen. It was found about 475 m a.s.l. We may presume that the transportation has not been especially long or rough. Near Dovre station, there is a ravine with a brook which on one side is enclosed by a steep slope formed of a compact, light moraine. This slope is weathered just like the Kvitskriuprestinn-moraine in Ula-valley, and also the material in the moraine shows a resemblance. However, there are no distinct pyramid

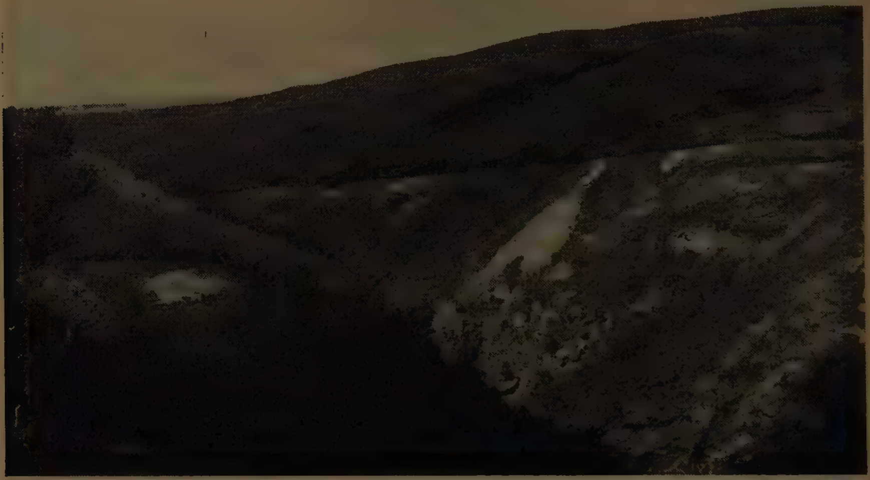

Fig. 7. The terraces along the east (in the background) and the west (to the left in the foreground) sides of the Skjerva-river valley. Just to the north of Skarvangen seter. The picture is taken near Storbekken in direction north. Photo A. Heintz.

earth-pillars, but very deep vertical cracks dividing the moraine-slope into narrow, high columns, which do not decrease very much towards the top. Unfortunately, I did not have much time to study the deposits in detail. If my impression is correct and the mentioned moraine-deposits near Dovre station correspond to those in the Ula-valley, it will prove that moraines of this kind have a greater extension. If they really are from the Riss-glaciation, it confirms STRØM's theory that the districts in the inner part of Gudbrandsdalen were comparatively undisturbed during the last glaciation.

We may thus conclude that the grinding mammoth-teeth discovered in Norway belong to three different river-systems, from three mountain-ranges: 1) The teeth from Skarvang, Vågå and Otta belong to the river-system Otta—Vågå—Skjerva — and thus to the Jotunheimen-region. 2) The tooth from Ula-valley belongs to the Rondane-region. 3) The tooth from Dovre belongs to the Dovre-region.

As for the two tusk-fragments (from Fåvang, HEINTZ 1945, and

Jessheim, BERCERSEN 1932) it is obvious, that they have been transported for some distance, and this makes it difficult to ascertain from which district they have come. We only know that they belong to the Gudbrandsdalen river-system.

The problem is, if we can give a more positive answer to the question: when and where did the mammoth live in Norway?

As we have heard, SOERGEL stated that «Das Mammot erschien in Mittel-europa mit dem Aufkommen eiszeitlichen Klimaverhältnisse, es erreicht mit dem Hochstand der Vereisungen seine grösste Verbreitung. In den Zwischen-eiszeiten ist es bei uns verschwunden. . . Es war den warmeren Klima und den weitgreifenden Bewaldung ausgewichen nach N und NO» (1941, p. 33). We must therefore presume, that the mammoth, following the retreating ice of the Riss glaciation, migrated through Denmark and S. Sweden into the mountain-district of central Scandinavia. In fact the find in Pilgrimstad confirms that the mammoth lived in central Sweden in the beginning of the last interglacial. As mentioned it is probable that some of the finds from Denmark also belong to the period when the mammoth migrated to the north. During most part of the last interglacial the climatic condition in Scandinavia and Denmark was probably the same as it is now, or slightly warmer. As the mammoth did not live in the forests, we have every reason to presume that it belonged to the fauna of the high mountains — in central Norway the districts round Jotunheimen, Rondane and Dovre.

The carcasses of mammoth which have been discovered in the frozen earth in Siberia have given us an opportunity to study the vegetation on which they lived. TOLMACHOFF (1933) gives a list of plants found in the stomach and between the teeth of the Berosovka-mammoth. I have asked Head-curator J. LID of the Botanical Museum, Oslo, to study the list and let me know which of the mentioned plants also can be found in Norway. Head-curator LID kindly gave me the following account: «*Hypnum flutitans* (=*Drepanocladus flutitans*) and *Aulacomnium turgidum* are two mosses which are very common in the mountains of Norway, and they are also very common in the Arctic. . . . *D. flutitans* is found on wet marshes, ... *A. turgidum* on dryer marsh or firm earth. Mosses are regarded as very poor food and animals do not usually eat them. . . . . . . But both these mosses are so plentiful in our mountains, that the mammoths probably have eaten them for want of better food, especially the leafy and juicy *Hypnum flutitans*.

Alopecurus alpinus Sm. is a widely spread grass in the Arctic. It is not known from Scandinavia, but from Greenland, Svalbard and Scotland. It thrives best on wet places e.g. grass-marshes. *Beckmannia eruciformis* (L) — a grass, which grows right up to the shore of the Polar-Sea in Siberia. A closely related species *B. syzigachne* is known from Norway.

Hordeum violaceum Boiss, et Huet, a grass which is known from the Caucasian, Iran and Iraq, but not from Scandinavia.

Agropyrum cristatum (L), a grass which is widely spread in Siberia, Mongolia and China. It is only found occasionally in Scandinavia.

Carex langopina (= *C. Lachenallii*) and *Ranunculus acris* (L) are common in the high mountains of Norway on hills and near the shore. *Oxytropis sordida* (Willd.) (=*Oxytropis campestris* (L) subsp. *scordida* (Willd.) Hartm.) can be found on the hills and moors of Finmark.

According to this list of plants, I think there is reason to believe that the vegetation in the high mountains of Norway would be quite adequate for the mammoth even to day». (LID, letter to the author, translated).

From other carcases of mammoth and rhinoceros, discovered in Siberia (TOLMACHOFF 1933, PFIZENMAYER 1926) one could determine traces of the following plants: undeterminable grasses, ericacea (probably *Vaccinium Vitis Idea*) remains of *Betula* and *Salix* and wood and needles of conifera as *Picea*, *Abies*, *Larix* and *Ephedra*. Four of these plants are common in Norway today, partly in the high mountains, and partly lower down in the valleys.

As a result of this comparison we can state, that the flora which we have in the high mountains today, and probably also had during the last interglacial period, seems to be suitable for the mammoth. Like the reindeer of today, the mammoth probably migrated lower down into the valleys in the winter, and its winter diet probably consisted mainly of branches of coniferas, betula and other trees, mosses and lichens. If the climatic condition during the last interglacial was almost similar to that of today, the mammoths have lived in the high mountain plains about 1000—1200 m a.s.l. If the climate was warmer, they could have found suitable places to live in still higher parts of the mountains, which now are covered by ice and snow. In the previously mentioned paper (1943, b), STRØM pointed out that the mammoth has lived in Norway «in arctic climate towards the end of the last interglacial period» (p. 18, translated). In my opinion there is no reason to believe that the mammoth only lived in Norway at the beginning and towards the end of the last interglacial, as was the case e.g. in Denmark. On the contrary I presume that the mammoths had their haunts in the Norwegian and partly in the Swedish high mountains, and probably also in the northern districts of Scandinavia (Lappland, Finmark), and that they lived here in great numbers throughout the last interglacial. During the last glaciation they returned from these places and from NE Russia to Central Europe. In this connection it is interesting to note, that, according to TOLMACHOFF (1933) «east of the White Sea.. in the basin of the Pechora River» mammoth-fragments «are just as numerous as in corresponding parts of western Siberia». It will be remembered, that the part of NE Russia referred to here, was not covered by the last glaciation, and therefore, in the same way as in Siberia, the fossil remains of mammoth were not removed or destroyed by ice. In the districts west of the White Sea, which were covered by the last glaciation, the «remains of *mammoth* are rare» (TOLMACHOFF 1933) exactly as in Scandinavia.

The mammoth is not the only representative of the fauna characteristic of the arctic districts in the glacial and interglacial period in Europe and Asia. Among the larger mammals the horse is mentioned as one of the most habitual companions of the mammoth. The woolly rhinoceros (*Coelodonta antiquitatis* Bl.) is also very common, besides reindeer (*Rangifer tarandus*) and bison (*Bison priscus*). The musk-ox (*Ovibos moschatus*) on the other hand is much rarer (OBERMAIER, 1924, PAVLOVA, 1906, PFITZENMAYER, 1926, SOERGEL, 1941, TOLMACHOFF 1939).

Of all these animals only musk-ox and reindeer fragments have been found in the interglacial deposits in Scandinavia.

In Denmark a fragment of the cranium of a *musk-ox* has been found in Bannebjerg near Hilderød (NORDMANN 1905) in moraine deposits. In Sweden two rather uncertain fragments of foot-bones of musk-ox have been described one from Døsebacka, Bohuslän (J. ALIN & SANDEGREN 1947, MUNTHE 1904), and the other from Frösön, Jämtland (O. KULLING 1945); in both places fragments of mammoth were discovered in the same localities. In Norway two well preserved vertebrae of musk-ox were found in 1913 near Indset in the northern part of the Dovre mountain-district ca. 425 m a.s.l., ca. 110 km north of Otta (BJØRLYKKE 1913, HOLTEDAHL 1953, REUSCH 1913, ØYEN 1913, 1916). The vertebrae were found ca. 8—9 m below the surface — in a railway-cut. They lay in a stratified gravel-layer approximately 1—2 m thick near the limit of the sand-layer underneath. On top of the gravel-layer there was a 2—3 m thick sand-layer with some stripes of fine gravel. This sand-deposit was in turn covered by 3—4 m of moraine. Both BJØRLYKKE and REUSCH, who had visited the section the same summer as the discovery was made, pointed out, that the sand and gravel-deposits beneath the moraine must probably belong to the interglacial deposits. In any case the vertebrae of the musk-ox are so well preserved, that it is out of the question that they had been transported for a long distance. Any way the rather fragile bones could not have stood being carried away by the ice. These facts indicate, that the deposits where the bones were discovered, really are of interglacial origin, and consequently supports STRØM's (1943 a, b) assumption that some districts of central Norway were comparatively untouched during the last glaciation.

Reindeer-fragments from interglacial time have only been found at Pilgrimstad in Sweden. A piece of a reindeer-antler was discovered here together with mammoth-bones. (KULLING 1945). The reindeer-fragments, which are quite often found in Denmark, are all from post-glacial time. NORDMANN, however, points out that some of these finds may have been from interglacial deposits. He especially mentioned one fragment of an antler discovered close to the farm Holbæk, near Christiansfeld (Slesvig), as possibly belonging to deposits («Rullestens-Dannelse») older than the last glaciation (NORDMANN 1905, p. 37).

In Norway fragments of reindeer-bones are only known from interglacial deposits in Blomvåg, NW of Bergen. (HOLTEDAHL 1953 UNDÅS 1942). But as there still are reindeer living in Norway, finds of reindeer-fragments are quite common, and people do not pay special attention to them. Therefore it is not impossible that some of the fragments found in Norway really may belong to «interglacial» animals. However, this cannot be proved as long as the circumstances of the finds are not known in detail. Even then it might be difficult to determine the age of the finds. Let us for instance take all the finds of mammoth grindingteeth in Norway: they do not give any direct evidence that the animals lived during the interglacial period. And if they had not been mammoth-teeth, but reindeer-antlers, no one would have regarded them as belonging to the interglacial.

This also applies to the teeth of *horses*, which there are plenty of in Scandinavia. NORDMANN writes that the oldest horse-fragments found in Denmark, are from the Bronze-Age, and therefore believes that there were no wild horses in Denmark in late or postglacial time. Fragments of horses from the early Stone Age have been found in Sweden and Norway.

However, teeth of horses have been found in various parts of Norway and in different deposits. In most cases they are certain fragments of more or less recent animals, but it is often very difficult to tell their age.

It is quite probable that the wild horse and also the reindeer and musk-ox, followed the mammoth on its retreat from Central Europe to the Scandinavian Mountains at the beginning of the last interglacial period. If we remember that both in Central Europe and in Siberia there were more remains of wild horses (also *Equus cabalus fossilis*) found together with the mammoth than that of any other animal (SOERGEL, 1941, PAVLOVA, 1906), it would be very strange if the horse had not followed the mammoth into the high mountains of Scandinavia, too. A more close investigation of the finds of horse-teeth, will perhaps show, that also the wild horse belongs to our interglacial fauna.

Additional Remarks.

After having received the first proof of this paper, I have read the paper of B. A. TICHOMIROV and L. A. KUPRIJANOVA: «Issledovanie pylzy is rastitelnych ostatkov picshhi Beresovskago mamonta»

(«Investigation of pollen in the vegetable food-remains from the Beresovka-mammoth». Doklady Akademii Nauk SSSR, Vol. XCV, No. 6, 1954). In this paper the authors describe the results of a pollenanalysis of the stomach-contents of the Beresovka-mammoth. About 3 gr. were studied and about 8220 pollen-grains were isolated. The greater part of the pollen belongs to grasses (7966 or 97,09 %), only 13 (0,17 %) to different trees (*Abies*, *Alnus*, *Betula* and *Salix*) and the rest to half-grasses and various meadow plants. In the conclusion, the authors state that the mammoths lived in a more temperate climate than that which is found in the Beresovka-district today, and that the Beresovka-mammoth in fact at the moment of its death, lived in the forest zone. This conclusion, however, contradicts the investigations on the distribution of mammoths made in Europe and America (SOERGEL 1941, OSBORN 1942).

I have asked Professor K. FÆGRI, Bergen to look through the analysis-results, and in a letter to me he says that it is difficult to give a definite conclusion based on the published list (52 different plants). According to FÆGRI it is, however, most probable that the Beresovka-mammoth have lived during sub-arctic conditions, corresponding to the birch zone in the Norwegian mountains, perhaps somewhat higher up.

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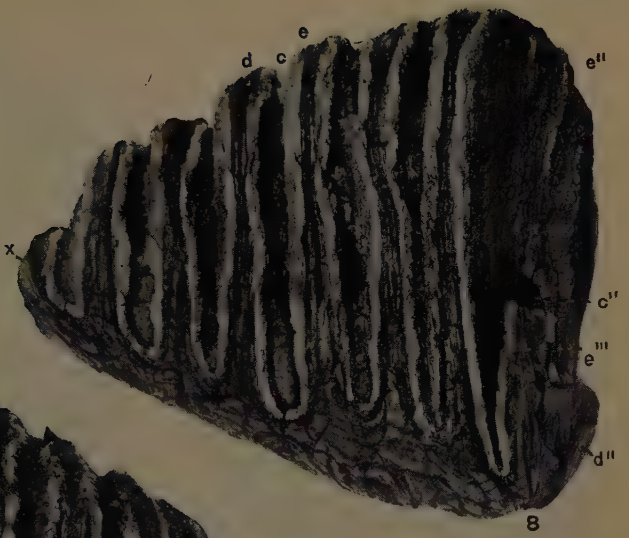
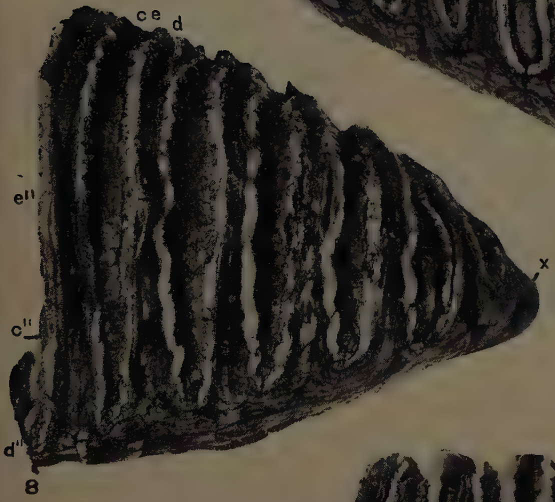
Manuscript received February 23, 1954.

PLATES I — II

Plate I. The tooth from Vågå seen from the left (A), and right (B) and the grinding surface (C).

c, c' and c'' — cement, d, and d'' — dentin, e, e', e'' and e''' — enemal, x — fragment of a enamel ridge. 8 — the bottom of the 8th enamel-fold. Photo B. Mauritz.





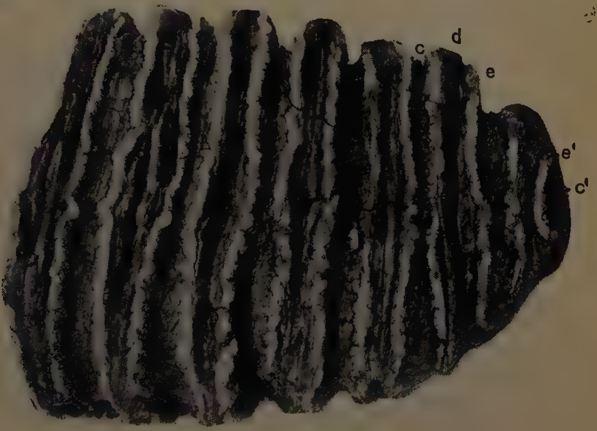


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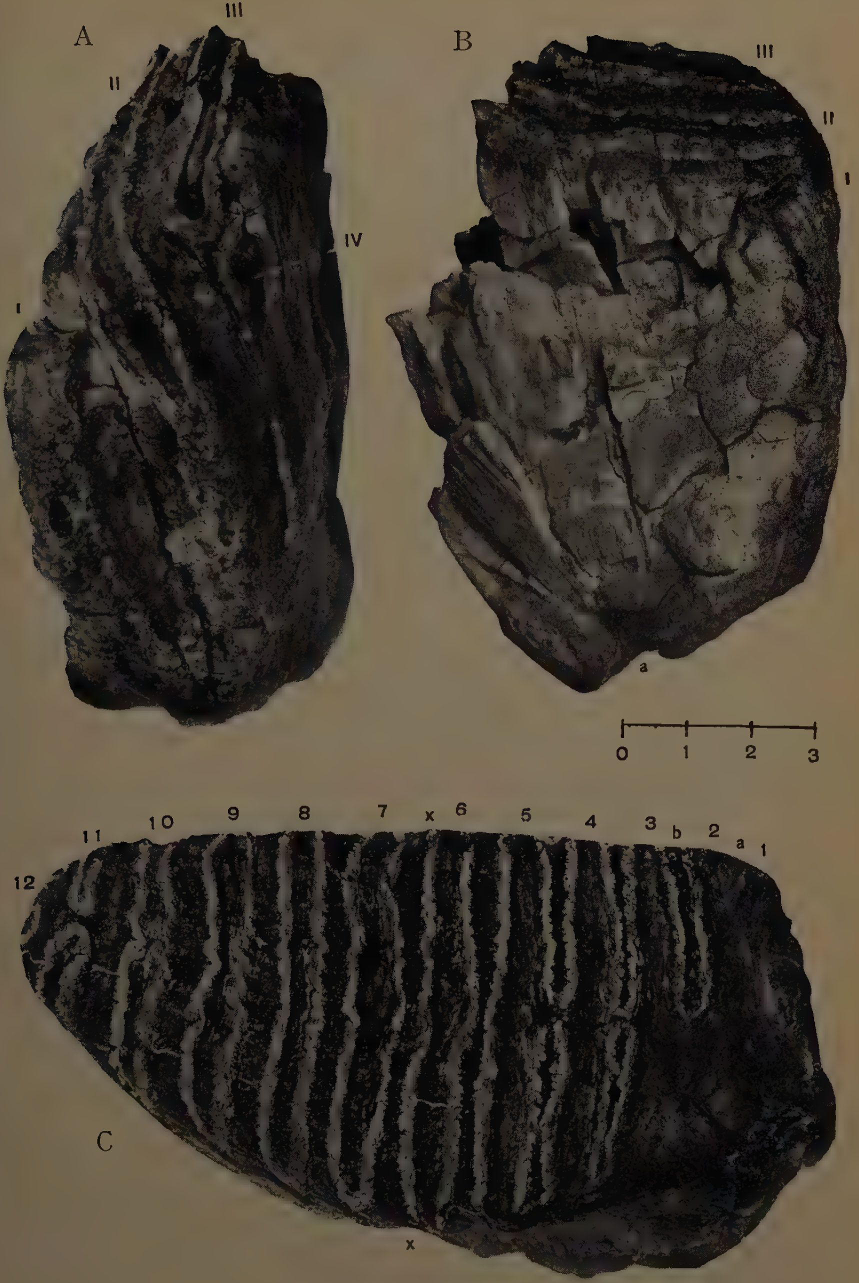
Plate II. A and B — the tooth from Ula seen from the left (A) and from the front (B). I, II, III and IV — enamel-ridges. Photo B. Mauritz. C — Grinding surface of the tooth from Skarvangen (Vågå). a — the triangular shaped spot, indicating a completely worn enamel fold. b — the bottom of the enamel fold between the enamel-ridge 2 and 3. x-x — the «single enamel-stripe» according to Collett. 1 to 12 — the number of the singel enamel-ridges. Photo B. Mauritz.

Plate II



NORSK GEOLOGISK TIDSSKRIFT 34

MIDDLE CAMBRIAN STRATIGRAPHY IN THE RØYKEN AREA, OSLO REGION

BY

NILS SPJELDNÆS

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Abstract: The Middle Cambrian beds, which are the oldest ones in this area, are described from a number of localities. The basal beds are of different age in the different localities and the facies change rapidly. This is explained by a marked topography in the basement, probably due to Precambrian faulting along a system of fractures which were active also in the Permian. In other areas of the Oslo region the change in facies in the Middle Cambrian can probably be explained in the same way, and not by Caledonian thrust faulting.

Introduction.

The Røyken area lies on the western side of the Oslo fjord, about 30 km SW of Oslo. The area mainly consists of Precambrian rocks, dissected by numerous faults. Cambrian and Ordovician sediments are preserved on some of the subsided Precambrian blocks.

The geology of the area has been dealt with by BRØGGER (1882), who described the stratigraphy and palaeontology of the Cambrian and Lower Ordovician, and also made some notes on the Permian eruptives. Later BRØGGER (1886) also mentioned some general (tectonic) features of the area. STRAND (1929) described some Middle Cambrian fossils and mentioned localities at Slemmestad. GLEDITSCH (1944, 1952) has studied the Precambrian rocks of the area, and also mentioned the occurrence of Cambrian basal sediments at several localities.

The author is deeply indebted to Prof. L. STØRMER and Dr. G. HENNINGSMOEN for valuable advice and discussions in connection with this paper.

Description of Localities.

Slemmestad. There are several Middle Cambrian localities in or near Slemmestad (text fig. 1, loc. 1—4).

In the road section just south of the centre of Slemmestad, on the road to Nærsnes, the basal beds of the Cambrian are well exposed, resting on the Precambrian. (text fig. 1, loc. 2, text fig. 2). The latter is represented by a deeply weathered granite, which contains some scattered quartz pebbles in its upper part. On top of this conglomeratic arkose we find a thin layer (2—6 cm) of light, tough fragment limestone, followed by 30—40 cm of bedded, arenaceous dark limestone. Above this is a thin arkosic layer (3—10 cm) followed by unfossiliferous, dark carbonaceous shale (alum shale), of which up to 1 m is exposed.

The arkosic layer converges towards the basal arkose, which has a slightly steeper slope towards the north. All beds between the two arkose layers seem to thin out gradually, with no signs of squeezing. This indicates that the basal limestones were not deposited on a horizontal surface. The angle between the arkose beds possibly corresponds to the slope of the original Precambrian surface. The upper arkose probably represents an outwash of coarse sediment over the limestone. It mainly consists of angular fragments of the local granite. However, we also find an abundance of other rocks, such as quartz and fragments of dark shale and limestone. The thickness varies, and the lower surface is undulating (text fig. 2).

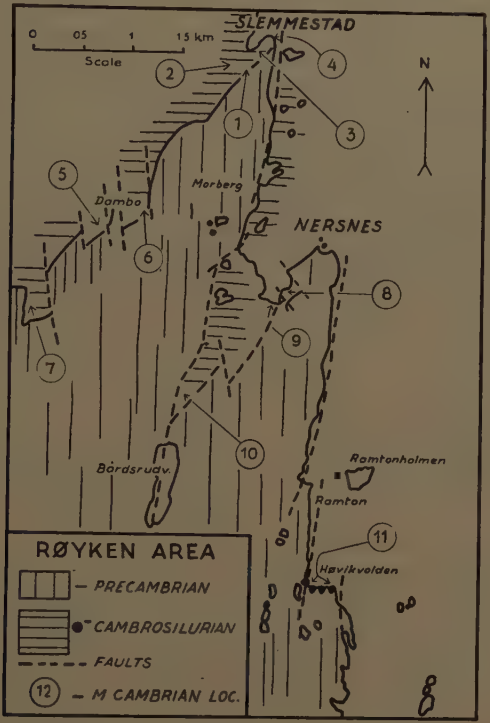

Fig. 1. Map of localities in the Røyken district. The map is slightly modified from Gleditsch 1952. Localities: 1) Road section just south of the centre of Slemmestad. 2) Lortbekken (not exposed at present). 3) Section south of the road from Slemmestad to the public harbour. 4) Exposure just south of the public harbour, Slemmestad. 5) Section of a brook near Dambo. 6) Section of the road between Dambo and Morberg about 900 m SE of Dambo. 7) Large exposures of conglomerate between Dalbø and Auke. 8) Old quarry at Nærsnes. 9) Section along the brook by the football field, Nærsnes. 10) Small section near the road from Nærsnes to Bårdsrudvann. 11) Numerous small exposures at Høvikvolden.

In the lower limestone we find the following fossils:

Ptychagnostus (Triplagnostus) gibbus	few specimens
Solenopleura parva	not common
Solenopleura munsteri	common
Paradoxides paradoxissimus	very common
Hyolithes spp	few specimens
Inarticulate brachiopods.	

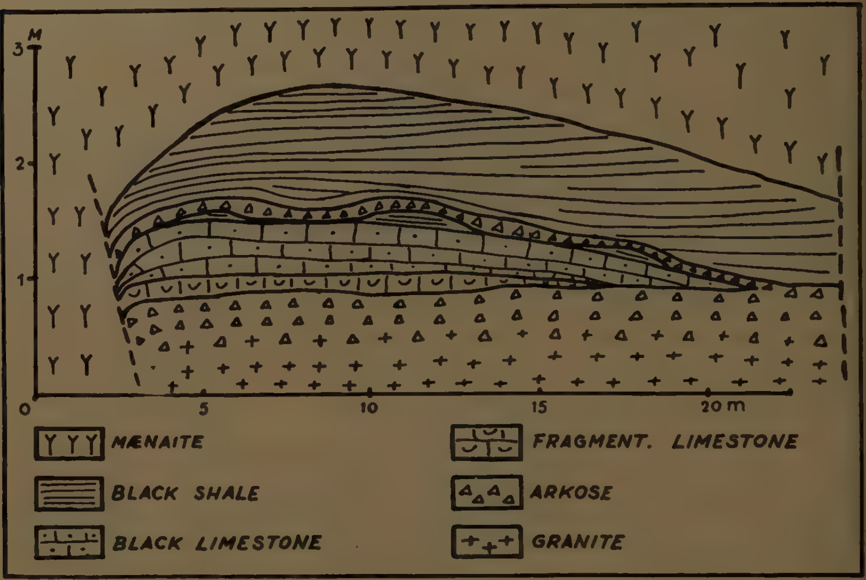

Fig. 2. Section of the locality just south of the centre of Slemmestad (text fig. 1, loc. 1). The height in the figure is exaggerated three times in proportion to the length.

One finds the same fossils in the dark limestone, *Ptychagnostus* (*Triplagnostus*) *gibbus* is, however, dominating, in some cases preserved as complete specimens. In the upper arkose layer the only determinable fossil to be found is a pygidium of *Paradoxides paradoxissimus*. As mentioned above, the shale is unfossiliferous in this locality.

All the Middle Cambrian beds at this locality are preserved in a lens of sediments below a sill of Permian mænaite (see text fig. 2). Generally the sills occur close to the Precambrian surface, altering the Cambrian sediments, and thus obscuring the contact between the Cambrian and the Precambrian.

We find a large number of individual sills with thin layers or lenses of Middle Cambrian sediments in between. Most of the sills are of mænaite type, light, finegrained rocks consisting chiefly of plagioclase feldspar, others are camptonites, dark porphyric rocks, and others again resemble diabases (cfr. BRØGGER 1882).

The present material of observation indicates that there is a dif-

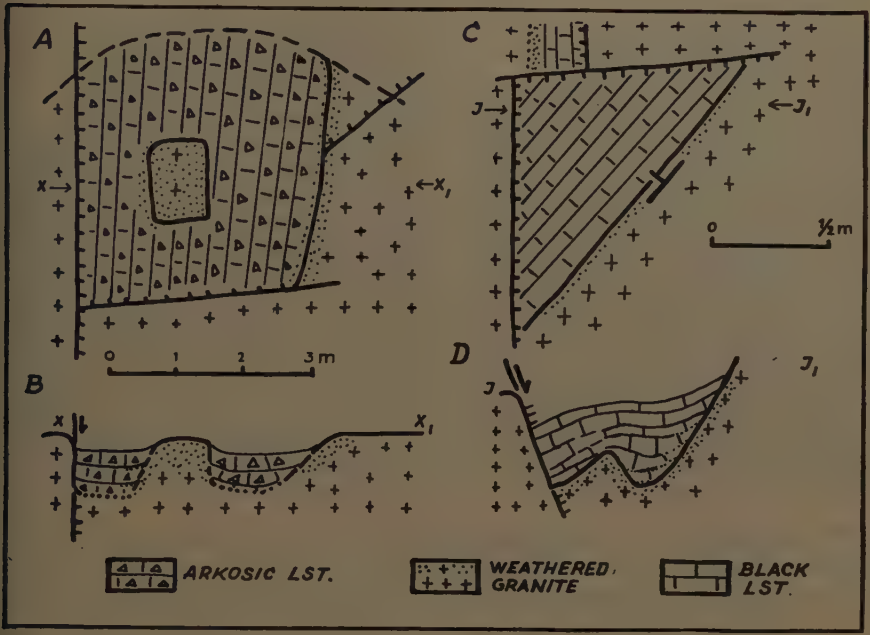

Fig. 3. Sketch maps (A, C) and vertical sections (B, D) of two exposures from Høvikvolden. The first one (A, B) yielded *Hypagnostus parvifrons mammilatus* and other fossils, the latter (C, D) *Ptychagnostus atavus* and other fossils. Faults are indicated by indentated lines and arrows.

ference in the degree in metamorphism caused by the various types of sills. The metamorphism seems to be stronger below the dark sills than below the mænaites. The diabase often occurs as more or less vertical dikes and as a combination of sills and dikes.

Fossils are found between the sills at Slemmestad. The locality lies by the road from the centre of Slemmestad to the public harbour. In this locality (text fig. 1, loc. 3) we find *Ptychagnostus punctuosus* in large stinkstone lenses in black shale. In layers further down there are indeterminable agnostids in similar stinkstone lenses and in the black shale. It is very difficult to estimate the total thickness of the Middle Cambrian because of the numerous sills and the intense faulting.

There is another Middle Cambrian locality on the shore just south of the public harbour (text fig. 1, loc. 4). The rocks are brecciated by a large permian fault, and the surface of the rocks is covered with cement dust from the large factory at Slemmestad. It is, therefore, difficult to interpret the geological structure correctly.

Fossils have been found in a small lens of sediments between two thick sills. The lens is only exposed at low tide with calm weather. The sequense is the same as in the road section at Slemmestad. At the base fragment limestone with *Paradoxides paradoxissimus, Solenopleura parva* and *Ptychagnostus* (*Triplagn.*) *gibbus* followed by dark bedded limestone with abundant *Ptychagnostus* (*Triplagn.*) *gibbus* and a thin (5 cm) layer of arkose. There are black unfossiliferous shales between the arkose and the upper sill. In this case the lower sill was evidently injected into the basal arkose, below the fragment limestone. The persistence of the thin arkose layer is remarkable. The distance between the two localities (text fig. 1, loc. 2 and 4) is about 500 m, and they are almost in the line of the strike of the beds. This fact corroberates the author's hypothesis that the basal beds were deposited on a hill sloping towards NNW.

An old locality was Lortebekken (text fig. 1, loc. 2). Here the Cambrian basal layers were developed as a calcareous conglomerate with numerous fossils in the matrix. The locality is no longer accessible due to housebuilding, and much of the material collected has been lost.

The locality was partly exposed for a short time in October 1953. The sequence was similar to that found in the road section (loc. 1, see below). On top of the precambrian there is a conglomeratic, light limestone with *Paradoxides paradoxisimus Solenopleura* spp. and *Ptychagnostus* (*Triplagnostus*) *gibbus*, a dark limestone with abundant *Ptychagnostus* (*Triplagnostus*) *gibbus*, underneath unfossiliferous, black shales.There is no upper arcosic layer in this locality. The basal beds are more conglomeratic than in the road section, containing numerous quartz pebbles and phosphate nodules. (The conglomerate was not accessible in October 1953, and the description is based on specimens preserved in Paleontologisk Museum, Oslo, collected by Prof. L. STØRMER).

In Paleontologisk Museum, Oslo, there are specimens of *Hypagnostus parvifrons* preserved in shale from Slemmestad. They are

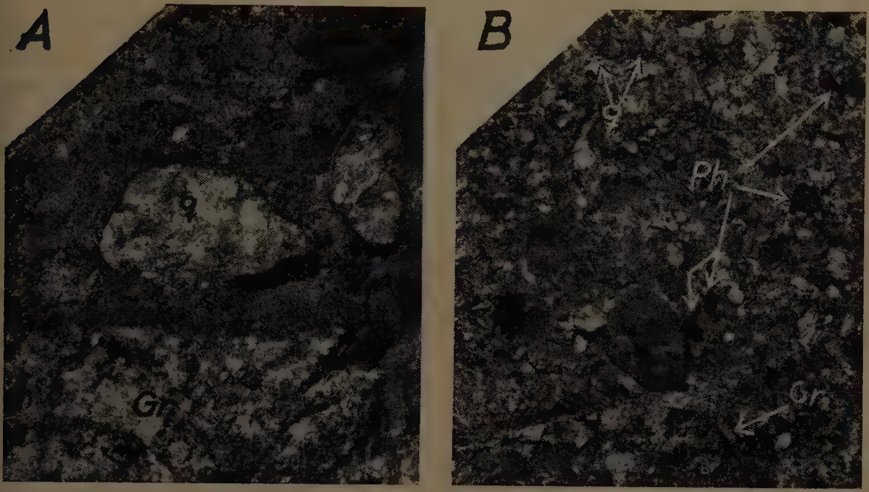

Fig. 4. Types of basal beds from the Røyken district. A is from loc. 6 (text fig. 1), showing quartz pebbles (q), and the sharp contact with the Precambrian granite. (Gr) *B*. is from Høvikvolden, showing angular fragments of granite (gr), rounded quartz pebbles (q) and black phosphatic rocks (Ph). Both figures are about 9/10 natural size. Photo. B. Mauritz.

refered to as «*Agnostus laevigatus*» by Brøgger (1882, p. 202). However, he used that term in rather a wide sense.

A fairly complete section of the Middle Cambrian is exposed in a brook near Dambo, about 2½ km SW of Slemmestad (text fig. 1, loc. 5). The rocks are altered, possibly by a thick camptonite sill, and no fossils have been found. (The metamorphism might, in this case also be due to the Permian Drammen Granite, which is exposed about 3 km to the west).

The basal beds are like those found at Slemmestad. They rest upon an arkose with very little foreign material. The lower light limestone (10 cm) and the upper, dark limestone (40 cm) are altered into hornfels. In this locality there is none of the upper arkose found in localities 2 and 3.

Above the lower ½ m there is 8—9 m of black shale with a few, large stinkstone lenses, interrupted by the sill about 5 m above the base.

Between Dambo and Morberg, the basal beds are exposed in a locality on the southern side of the road (text fig. 1, loc. 6). A conglomerate rests upon a smooth, but slightly irregular surface of fresh, unweathered granite.

The grain-size varies considerably, ranging from a coarse sandstone to pebbles more than 15 cm in diameter. The coarse conglomerate appear as lenses wedging out towards the south (against the slope of the Precambrian surface). In the opposite direction the lenses grade into finer conglomerate. This indicates that also in this locality the basal sediments were deposited on a hill sloping towards the north.

The pebbles are generally well rounded, and consist mainly of quartzites and other hard rocks, most of which do not appear in the local bedrock. (text fig. 4 A). A few pebbles of light limestone and sandy to conglomeratic carbonaceous rock have also been found. Due to the metamorphosis, however, it was impossible to find fossils in these pebbles. Quartz, probably pegmatite quartz, dominates among the smaller pebbles (2—5 cm).

Resting on the conglomerate, which is 25 to 40 cm thick, is an arkose, similar to that found at Slemmestad (in the upper layer). It is dark, probably coloured by carbonaceous matter, and mainly consist of angular fragments. The percentage of local material seems to be lower than in Slemmestad. The thickness of the arkose is up to 75 cm. No younger beds are preserved in this locality.

The beds slope slightly towards the north. The Precambrian rock rises steeply above this plane of bedding just south of the locality. No fault line has been observed along the angular junction, and this indicates that the locality is a fraction of one of the Cambrian shorelines. This is corroborated by the wedging out of the conglomerate towards the south.

At Dalbø, and north of Auke, the basal beds are exposed over a large area. (GLEDITSCH, 1952), (text fig. 1, loc. 7). They vary to a certain degree. Generally an arkose consisting of granitic detritus rests upon the Precambrian with a more or less sharp border. In some cases the arkose was deposited on a comparatively unweathered granite, and in other cases there is a gradual transition from deeply weathered granite to arkose. Above the arkose there is a conglomerate with boulders of various rocks, granite, quartz, quartzite and conglomerate or arkose. The thickness of the arkose and the conglomerate is up to 1½ m. On top of the conglomerate there is a thin, light limestone (5—10 cm) followed by dark limestone and black shale. The sediments have been extensively altered by the Drammen Granite, and there are no fossils. The conglomerate from this locality was described by Reusch (1884), who especially mentioned the presence of pebbles of conglomerate in the conglomerate. It is not unusual to find such boulders together with pebbles of sandstone, arkose and phosphates, even if they only make up a minority of the pebbles of the conglomerate. The pebbles of this type are angular, and do not differ visibly from the sediment underneath. This indicates that the final conglomerate was formed by erosion of older, probably local sediments.

There is a considerable amount of galena and other sulphides in the coarse sediments in the Røyken district. They also appear in veins in the Precambrian rocks. The localities at Slemmestad and Dalbø are specially rich on sulphides. On the latter area some mining of argentiferous galena has been done. (cf. Reusch 1884). One has found galena in Cambrian basal sediments in Sweden, too, and it is supposed to be of sedimentary origin. In contrast to the Swedish deposits, the galena in the Røyken distrikt is accompanied by quantities of pyrite and zinc-blende. The presence of this paragenesis might indicate a pneumatolytic origin of the sulphides in connection with the numerous Permian eruptives of the region. However, this is probably not the case at Slemmestad, where the arkose is very rich on sulphides, while the unmetamorphic limestones are practically devoid of ore minerals. The sulphides in the fine sediments (mainly in the black shale, and a little in the dark limestone) are arranged in bands parallel to the bedding. Generally these bands also contain a large amount of sand or silt. The sulphide grains are of silt size, too, or smaller, except for some recrystallised clusters which probably are of secondary origin. The sulphide grains found in the arkose are more irregular both as to shape and size, indicating that the ore minerals were deposited as heavy minerals in the sediments.

In the Nærsnes district (for geological description, see Brøgger 1882 and Gleditsch 1924, 1952), the Middle Cambrian rocks are exposed over a comparatively large area. The geological structure is similar to that found at Slemmestad, a faulted block of Precambrian sloping N—NNW, covered with Cambrian and Ordovician sediments, with the oldest beds at the southern margin of the area. The Middle Cambrian rocks are penetrated by numerous sills, some of them of different types to those found at Slemmestad. BRØGGER (1882) has given a description of some of the types, which occur both as sills and dikes. The tectonics of the oldest beds are therefore very complicated, and in the same way as at Slemmestad, no exact figures of the thickness of the beds can be given.

In spite of the widespread occurence of Middle Cambrian sediments in Nærsnes, determinable forssils have only been found in two localities. In the first one, an old quarry on the southern side of the Nærsnes bay, (text fig. 1, loc. 8) we find *Hypagnostus parvifrons* in a black stinkstone lens, and about 2—4 m higher there is *Peronopsis fallax ferox* in altered shale. The latter form is represented by specimens intermediate between this subspecies and *Peronopsis fallax fallax*, like those figured by WESTERGÅRD (1946, pl. 3 figs. 1—2) from the zone of *Ptychgnostus punctuosus*. It is therefore taken for granted that both this zone, and that of *Hypagnostus parvifrons* occur in this locality. Besides the other fossils, indeterminable agnostids (*Ptychagnostus* sp. ?) occur in masses in the shale in both zones.

The basal beds are exposed on the road along the southern side of the bay. No fossils have been found here. The rocks are an arkose, consisting mainly of detritus of the local granite, mixed with a few pebbles of quartz. The thickness of the arkose, which grades into the granite, is up to one meter. The contact surface between the arkose and the granite, which has been studied in detail, is very irregular, indicating a smallscale relief of the Precambrian surface. The «topography» consists of domeshaped areas of granite, a couple of meters broad and less than one meter high. In the granite there are irregular steep-sided furrows filled with arkose.

In this locality the arkose is followed by a sill, obscuring the transition to the black shale. In a small quarry NE of the first mentioned locality, the arkose is found in contact with a small patch of black shale. There is no bedded limestone at the bottom.

In another locality, in the bed of the brook by the football field, (text fig. 1, loc. 9), the Middle Cambrian shale rests directly upon the irregular, slightly weathered surface of the granite. Here there is no arkose.

The other locality at Nærsnes, where fossils have been found, was described by BRØGGER (1882, p. 199) (text fig. 1, loc. 10). It lies in the southwestern part of the Nærsnes district. The fossils are found in a dark, slightly metamorphic shale. BRØGGER (l.c.) reported *Paradoxides rugulosus* and «*Agnostus laevigatus*». It is obvious that BRØGGER used the latter term in a much wider sense than *Lejopyge laevigata* of modern authors, e.g. WESTERGÅRD (1946). All the agnostids from this locality, both those collected by BRØGGER, and those found by the author, are undeterminable as to genus and species. Most of them probably belong to *Ptychagnostus*. A few are smooth, but it is impossible to refer them to *Lejopyge laevigata* because of the bad state of preservation. *Paradoxides rugulosus* only appears in fragments, and is identified by the characteristic sculpture, and on a fragmentary pygidium. In addition to the trilobites mentioned by BRØGGER, the author also found *Agraulos* cf. *acuminatus* (BRØGGER). The specimens which were found are transitional forms between the typical *Agraulos acuminatus*, and the type described by BRØGGER (1878 pl. 4 fig. 5) from stage 1 c. The two types differ considerably in the development of the preglabellar field, which is large and triangular in front, in *acuminatus*, and smaller and evenly rounded in the older type. The specimens from Nærsnes are closer to the typical form than to the older one, which, according to oral communication with dr. G. HENNINGSMOEN, might be a separate species.

The fauna, therefore, indicates that the layers belong to the lowest part of stage 1 d, or to the transitional beds between 1 d and 1 c. It is the only locality in the Røyken district, where the stage 1 d is found.

The author's interpretation on the geology of the Nærsnes area slightly deviates from that expressed in the earlier maps and descriptions (BRØGGER 1882, GLEDITSCH 1944, 1952). The border between the Cambrian and the older rocks is a fault line. (cf. text fig. 1). In some places there are large diabase dikes along this line. In the locality mentioned above, (loc. 10), the geological structures are obscured by heavy vegetation. However, it seems to be evident that there are Precambrian rocks on both sides of the brook, and that there is no conglomerate in this place. Therefore there is probably a faultline on the northern side of the stream, a few meters south of the exposure where the fossils have been found. (Compare Brøgger 1882, text fig. on p. 199).

At Høvikvolden (text fig. 1, loc. 11) the basal layers of the Middle Cambrian are exposed as a thin crust of calcareous conglomerate sloping to the north or north-west (cf. Gleditsch 1944). We find the conglomerate in a large number of presumably original depressions in the Precambrian surface. The dimensions of these depressions vary from less than 10 cm to more than 50 m. They are generally limited by straight lines, corresponding to joints in the Precambrian granite. (text fig. 3). Movements have taken place along some of these lines in Permian time, this being inicated by small friction breccias. We also find a number of large breccias and quartz-filled veins between the depressions. In some cases, however, the Cambrian basal beds show grading along the steep walls of the depressions, indicating that the conglomerate and limestone originally were deposited in cavities formed by erosion in the jointed Precambrian rock. In this area we come across many depressions of similar size and shape, now filled with pleistocene or recent gravel.

There are two different types of Cambrian basal sediments at Høvikvolden. In most cases the rock consists of an arkose or conglomerate cemented with a grey limestone. The fragments, which are of an angular shape (text fig. 4 B). chiefly come from the granite underneath and from other local rocks. There are also a good deal of more rounded pebbles of quartz and quartzites. We find large pebbles (up to 15 cm in diameter) of a black, unmetamorphic sediment, probably a phosphatic sandstone with wellrounded quartz grains. In the depressions there are several subangular horsts of the Precambrian basement, and these reflect the irregular surface on which the Cambrian beds were deposited (text fig. 3).

The Precambrian granite is strongly weathered, and at times brecciated. However, the decomposed layer is rather thin, 5—15 cm, except in the horsts mentioned above, which are deeply weathered.

The limestone is fossiliferous, and contains the following fossils:

Hypagnostus parvifrons mammilatus.
Paradoxides paradoxissimus.

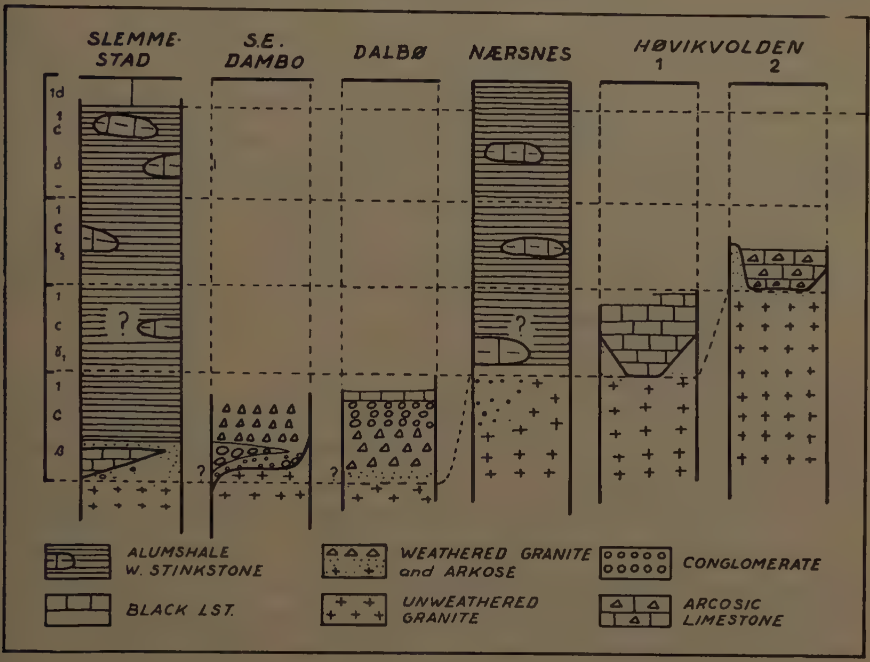

Fig. 5. Diagramatic section of the Middle Cambrian sequence in some localities in the Røyken district. The scale is not the thickness of the beds, only the zones present. The Slemmestad and Nærsnes sections are combined from localities 1—4 and 8—10 respectively, and specimens found in the collections of Paleontologisk Museum, Oslo.

Solenopleura parva.
Hyolithes sp.

In some of the depressions there are plenty of fossils, and in others there are none or very few. The quantitative composition of the fauna also varies. *Hypagnostus parvifrons mammilatus* is the most common species everywhere. *Paradoxides* can be found in most places, but in rather small amounts. There is a great deal of *Solenopleura* and *Hyolithes*, but they are not found in all localities.

We find the other type of sediments in two deep, triangular depressions. In one of them (text fig. 3 C—D) all the sediment was taken out in order to study the contact with the basement. The granite appears to be only slightly weathered. The sediment consists of dark, carbonaceous limestone with considerable quantities of sand and silt, and some thin fragment layers. The lowest layers are lightcoloured and marly. The bedding and the topography of the bottom of the depression, clearly indicate that the sediments were deposited in an original depression in the granite.

The fauna in this place consists of:

Ptychagnostus atavus.
Hypagnostus parvifrons mammilatus.
Paradoxides paradoxissimus
Solenpleura parva
Hyolithes sp.

The agnostides are evenly distributed in the layers, with *Ptyghagnostus atavus* in majority. The other fossils are found in the fragment layers, or in between them in the lowest beds of the depression. The total thickness of the layers of this type is 75 cm, the other depressions seem to be less than 40 cm deep. It is probable that the two types of sediment belong to two different zones. The first one, with numerous *Hypagnostus parvifrons mammilatus* probably belong to the zone of *Hypagnostus parvifrons*. However, the subspecies *mammilatus* is also reported to have been found in the zones of *Ptychagnostus atavus* and *Ptychagnostus punctuosus* (WESTERGÅRD 1946), but it is not common in these zones. The other type evidently belongs to the zone of *Ptychagnostus atavus*, the guide fossil being the most abundant. The layers of these two types are certainly not contemporaneous. The latter (with *Ptychagnostus atavus*) was deposited under euxinic conditions, whereas the first, in spite of containing some carbon, seems to have been deposited under ventilated conditions. Because of the intense faulting of the district, it is impossible to find the original vertical distance between the depressions. They are now all found at, or near sea level.

Correlation.

The faunal zones and subzones in the Middle and Upper Cambrian are remarkably constant all over Scandinavia. The difference between the regions lies in the lithology and the number of zones present. In the Røyken district the lowest zone found in the Middle Cambrian is that of *Ptychagnostus* (*Triplagnostus*) *gibbus*, just as in the typical section at Krekling, in Scania and in some of the northern districts in the Oslo region.

The table below shows the stages found in Norway, and their Swedish equivalents. The table is based mainly on data given by WESTERGÅRD (1946) and STRAND (1929, 1946). The symbols applied to the Norwegian zones are partly new and are the result of a cooperation between Dr. G. HENNINGSMOEN and the author.

Stage of	Zone of	Swedish symbol	Norwegian symbol	Thickness at Krekling[1]
Paradoxides forchammeri	Lejopyge laevigata	C 3	1 d γ	ca. 11 m
	Solenopleura brachymetopa	C 2	1 d β	
	Ptychagnostus lundgreni & Goniagnostus nathorsti	C 1	1 d α	
Paradoxides paradoxissimus	Ptychagnostus punctuosus (= z. of Par. rugulosus)	B 4	1 c δ	ca. 8 m
	Hypagnostus parvifrons	B 3	1 c γ_2	» 1,5 m
	Tomagnostus fissus and Ptychagnostus atavus	B 2	1 c γ_1	» 2,5 m
	Ptychagnostus (Tripl.) gibbus (= z. of Ctenocephalus exulans)	B 1	1 c β	» 5 m
Paradoxides ölandicus	Paradoxides pinus	A 2	1 c α	not developed
	Paradoxides insularis	A 1		

[1] from BRØGGER 1878.

The *Paradoxides ölandicus* zone, which is not developed in the Røyken district, is found in Norway in the Mjøsa district, and in Rogaland (STRAND (1929, 1948) and HENNINGSMOEN (1952).

In the Røyken district, the Middle Cambrian sedimentation started at different times at the various localities. At Slemmestad, the zone of *Ptychagnostus* (*Triplagn.*) *gibbus* is the lowest. At Nærsnes, the basal layers are unfossiliferous. The oldest datable zone is that of *Hypagnostus parvifrons* developed as a black shale with stinkstone lenses. At Høvikvolden both the zone of *Ptychagnostus atavus* and that of *Hypagnostus parvifrons* are represented in the basal layers. We find the latter zone in a facies quite different to that at Nærsnes. This difference in facies in this comparatively small district, indicates that the Precambrian surface must have had a marked topography, even if the variations as to altitude were not so large.

In the basal beds, phosphatic rocks are common in most localities. The rounded quartz grains in these rocks form a striking contrast to the generally sharply angular material which we find in the basal beds. At Dalbø one can also find pebbles of conglomerate in the conglomerate. However, the pebbles and the matrix are similar in this locality.

The phosphatic rock is rather soft and fragile and can hardly have endured long transport. The older Cambrian rocks were therefore probably sedimented in this area before the time of the zones of *Ptychagnostus* (*Triplagn.*) *gibbus*, and were eroded before this zone was deposited.

In the rest of the Oslo region, two facies of the Middle Cambrian have been found. In the first one, the sequence starts with 1 c *β*, and in the latter with 1 c *α*. (subzone of *Paradoxides pinus*, the lower subzone of *Paradoxides insularis* is not reported from Norway). The second type of facies is regarded as being allochtonous, and is found in the Mjøsa district, and in parts of Hadeland. (STRAND 1929, 1948). In the latter district we do not find any Lower Cambrian layers, and the *Paradoxides ölandicus* beds were regarded as belonging to a nappe because they are found 10 and 20 km respectively from two localities in which the Middle Cambrian have the first («autochtonous») development. In the Røyken district, however, we find changes in facies of the same order of size within a much smaller area.

Therefore it must be stressed that change in facies of the Middle Cambrian, even in a small area, generally is no proof of tectonical displacement of the beds.

Since no tectonical evidence for a nappe at Hadeland has been procured, it seems reasonable to conclude that the *Paradoxides ölandicus* beds in this district probably are autochtonous.

The Precambrian topography in the Røyken district was possibly determined by faults running NE—SW. Fault breccias in this direction have been described by BRØGGER (1886) and GLEDITSCH (1943, 1952). The faulting is regarded as being of Permian age only. However, both authors mention that there are at least two zones of breccia, of different age. The youngest one is dark-coloured by carbonaceous matter from alum shales, while the older ones are devoid of such material. Both BRØGGER and GLEDITSCH indicate the possibility of the older breccias being Precambrian. If this is correct, the Precambrian topography can easily be explained, even if the breccias are much older than the Middle Cambrian. Selective erosion of the rock on both sides of the faults, and along the faultlines themselves would have produced a marked relief. Another fact that must be mentioned, is that the *Paradoxides ölandicus*-locality at Røykenvik, Hadeland lies near one of the large faultlines bordering the Oslo region.

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TRONDHJEMSSKIFRENE VED MOLDE

AV

IVAR HERNES

INNHOLD

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Abstract. The schists near Molde form a syncline in the North-Western Gneiss Area of Southern Norway. They are mainly mica schist and green schist. The mica schist is believed by the author to correspond to the Røros Group of the Trondhjem Region, and the green schist to the Bymark-Støren Group of the same area, which would date them as Cambro-Lower Ordovician. The folding of the schists, and a trondhjemitization — granitization of a part of the mica schist, are of Caledonian age.

Forord.

Feltarbeidet for denne avhandling ble påbegynt sommeren 1949 med en geologisk undersøkelse av Molde omegn og Moldeøyene for Norges Geologiske Undersøkelse, Oslo. Sommeren 1953 fikk jeg anledning til å fortsette arbeidet, og både det tidligere undersøkte felt og området langs Fannefjorden ble besøkt. Feltarbeidet i 1953 ble bekostet av Geologisk Institutt, Universitetet i Bergen.

Bearbeidelsen av det innsamlete materiale er utført ved Geologisk Institutt, Norges Tekniske Høgskole, Trondheim, og Geologisk Institutt, Universitetet i Bergen.

Jeg vil takke bestyrerne av disse institutter, professor dr. TH. VOGT og professor dr. NIELS-HENR. KOLDERUP, og fhv. direktør for Norges Geologiske Undersøkelse, dr. C. BUGGE, for den velvilje de har vist.

Stud. real. I. BRYHNI deltok i feltarbeidet i 1953. Frk. ELLEN IRGENS har tegnet kartene. Preparant A. IVERSEN og preparant M. SØGNEN har laget tynnslipene. Jeg vil også takke for denne verdifulle hjelp.

Geologisk Institutt, Universitetet i Bergen, mars 1954.

Innledning.

Det undersøkte område ligger ved nordvest-kysten av Syd-Norge. Oversiktskartet fig. 1 viser beliggenheten av det kartlagte felt. Det strekker seg langs Moldefjorden og Fannefjorden, som er en gren av Romsdalsfjorden.

På øyene i Moldefjorden og på øya Tautra lengere vest fant C. BUGGE i 1933 grønne skifre, som han betraktet som en fortsettelse av Surnadalsfliken i Trondhjemsfeltet (BUGGE 1935). Han antok at de grønne skifre svarte til Trondhjemsfeltets grønnsteiner som danner den underordoviciske Bymark-Størengruppen. I sin avhandling innførte BUGGE betegnelsen grønne trondhjemsskifre om skifrene på Moldeøyene og på Tautra.

Trondhjemsskifre er en naturlig fellesbetegnelse for de kambrosiluriske bergarter i Trondhjemsfeltet og i utløpere fra Trondhjemsfeltet. I dette arbeide har jeg derfor brukt betegnelsen trondhjemsskifre om de bergarter ved Molde som danner en fortsettelse av Surnadalssynklinalen i Trondhjemsfeltet, og svarer til Trondhjemsfeltets kambro-underordoviciske dannelser.

T. GJELSVIK har funnet en vestlig fortsettelse av draget, idet det står grønnskifer på sydsiden av Romsdalsfjorden ytterst ved utløpet (GJELSVIK 1951, 1953). Mine undersøkelser på Moldeøyene viser at ved siden av grønnskifer finnes det her også betydelige mengder med

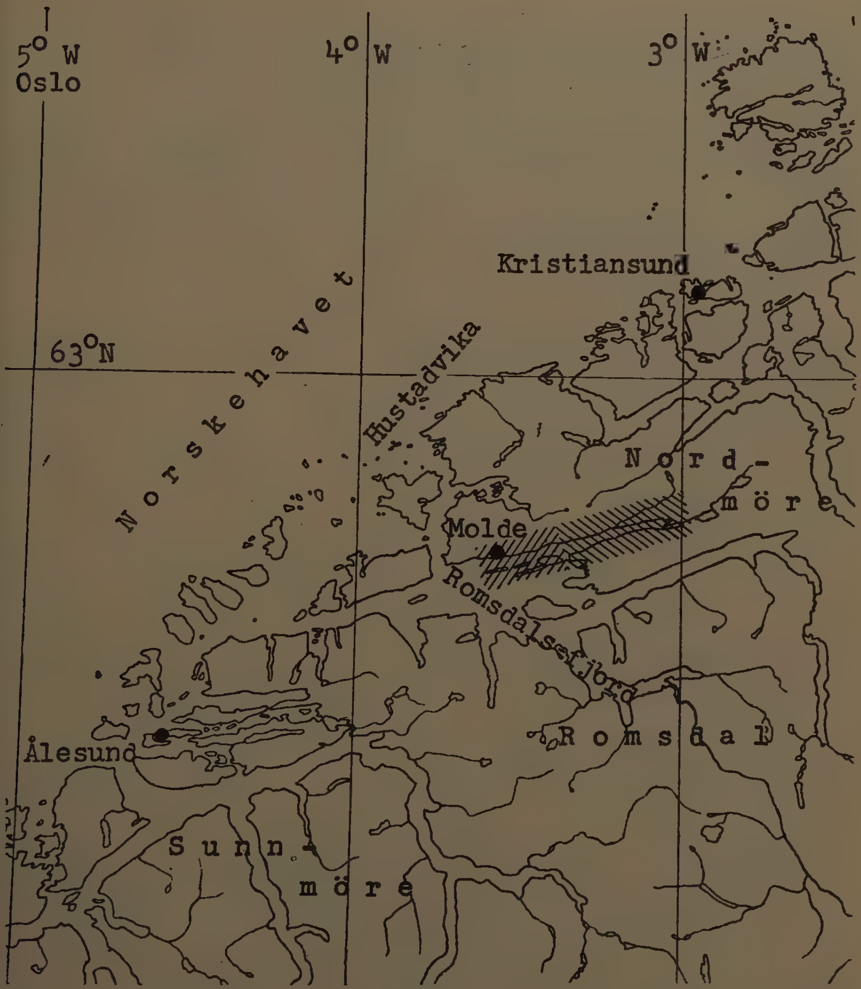


Fig. 1. Det skraverte felt viser beliggenheten av de undersøkte områder. (Fig. 2 og 3).
The hatched square shows the position of the investigated areas. (Figs. 2 and 3).

glimmerskifer. Mellom Moldeøyene og Surnadalsfliken har jeg funnet et sammenhengende drag med grønnskifer og glimmerskifer på sydsiden av Fannefjorden.

Skifrene, som ligger i gneiser, danner en synklinal i det nordvestlige gneisområdet i Syd-Norge. En kort beskrivelse av gneisene på Moldehalvøya er gitt i et tidligere arbeide (HERNES 1954). Her er tatt med en oversikt over tidligere undersøkelser.

Nedenfor vil bli gitt en beskrivelse av trondhjemsskifrene på Moldeøyene og på sydsiden av Fannefjorden. Skifrene og de omgivende gneiser er tegnet inn på to geologiske kart, fig. 2 og 3. Kartene grenser til hverandre. Fig. 2 omfatter Moldeøyene, og fig. 3 er over området ved Fannefjorden.

Geologi.

Moldeøyenes skifre.

Moldeøyene består av tallrike små holmer og skjær, og noen få litt større øyer. Den største øy er Bolsøy, som med et eide er forbundet med Forøy. Øyene er langstrakte, lave strøkøyer. Lengderetningen følger strøket som varierer fra østlig til øst-nord-østlig. Fallet er overveiende sydlig.

Moldeøyene er bygget opp av trondhjemsskifre, unntatt Forøy og den sydlige del av Bolsøy hvor det står gneiser. På Bolsøy grenser gneisen i nord til et glimmerskiferdrag. Langs grensen mellom gneisen og glimmerskiferen opptrer en smal sone med en mørk, biotitførende kvartsskifer. Kvartsskiferlaget er bare noen få meter mektig. Det er overalt iakttatt på grensen mellom gneis og glimmerskifer.

Glimmerskiferdraget danner den sentrale del av Bolsøy. Draget fortsetter vestover langs sydsiden av Sæterøy og Ramsøy, og danner dessuten flere mindre holmer og skjær syd og øst for Sæterøy.

Glimmerskiferen har som regel en fiolett tone. Hovedmineralene er biotit og kvarts. Glimmerskiferen er for den større del granatførende. Den er en typisk sedimentogen bergart.

I glimmerskiferdraget, og spesielt i den sydlige del mot gneisgrensen sees en del amfibolit og trondhjemit, og skiferen minner tildels om båndgneis. Amfiboliten er en epidotamfibolit. Den opptrer som ganger og linser overveiende parallell foliasjonen, og må oppfattes som metamorfe intrusiver. Trondhjemiten opptrer som lagerganger og linser. Dessuten ses også gjennomsettende trondhjemitganger. Trondhjemiten må være yngre enn amfiboliten, idet den skjærer gjennom amfibolit. Trondhjemitgangene og slirene må oppfattes som dannet ved en mekanisk injeksjon av trondhjemitisk magma i glimmerskiferen. Ved siden av denne mekaniske injeksjon har trondhjemitisk materiale metasomatisk fortrengt en del av den opprinnelige glimmerskifer. Karakteristisk for skiferen mot gneisgrensen er porfyroblaster av oligoklas. Skiferen viser altså en begynnende trondhjemitisering.

I glimmerskiferdraget, og spesielt like ved dragets nordgrense, opptrer flere smale soner med kalkstein. Mektigheten av kalksteinslagene ligger på omkring en ½ m, og de har således ingen økonomisk interesse.

Kalksteinen er tildels hvit til blålig hvit, tildels mer gråblå og finkornet. Den mikroskopiske undersøkelse viser at den gråblå type har vært utsatt for en sterk oppknusing med delvis nykrystallisering av mineralkornene. Ved siden av denne sedimentogene kalkstein opptrer ganger og linser med hydrotermal kalkspat.

Kvartsit er også funnet som smale soner i glimmerskiferdraget, spesielt ved nordgrensen. Analogt kalksteinen opptrer ved siden av den sedimentogene kvartsit, slirer og linser av hydrotermal kvarts.

Glimmerskiferdraget grenser i nord til et drag med grønnskifer.

Mot grønnskifergrensen opptrer i enkelte soner hornblende sammen med biotit, og vi får en grønnlig bergart. Hornblenden danner tildels store porfyroblaster, slik at man kan se de enkelte hornblendekrystaller, og bergarten kan beskrives som en hornblendeporfyroblastskifer. Smale soner med grønnskifer ses også i glimmerskiferen.

Grønnskiferdraget kan følges fra Bolsøy vestover langs Sæterøy og sydsiden av Gåsøy og videre langs sydsiden av Hjertøy, og det danner dessuten en rekke mindre øyer, holmer og skjær.

Grønnskiferen er en sterkt grønn, skifrig bergart. Den viser praktisk talt ingen mineralogisk variasjon. Skiferen består vesentlig av hornblende. Lengden av hornblendenålene er fra 0.2 mm til 0,4 mm. Sammensetningen av grønnskiferen er nærmest basaltisk. Etter dens geologiske opptreden sammen med suprakrustale bergarter, kan en derfor anta at grønnskiferen representerer omdannete basaltiske lavaer.

I grønnskiferen opptrer svovelkisrike soner, til dels sees rene svovelkisganger. Disse er av liten mektighet, men kan være meget utholdende. En tre-fire cm mektig svovelkisgang ble fulgt i ca. 30 m

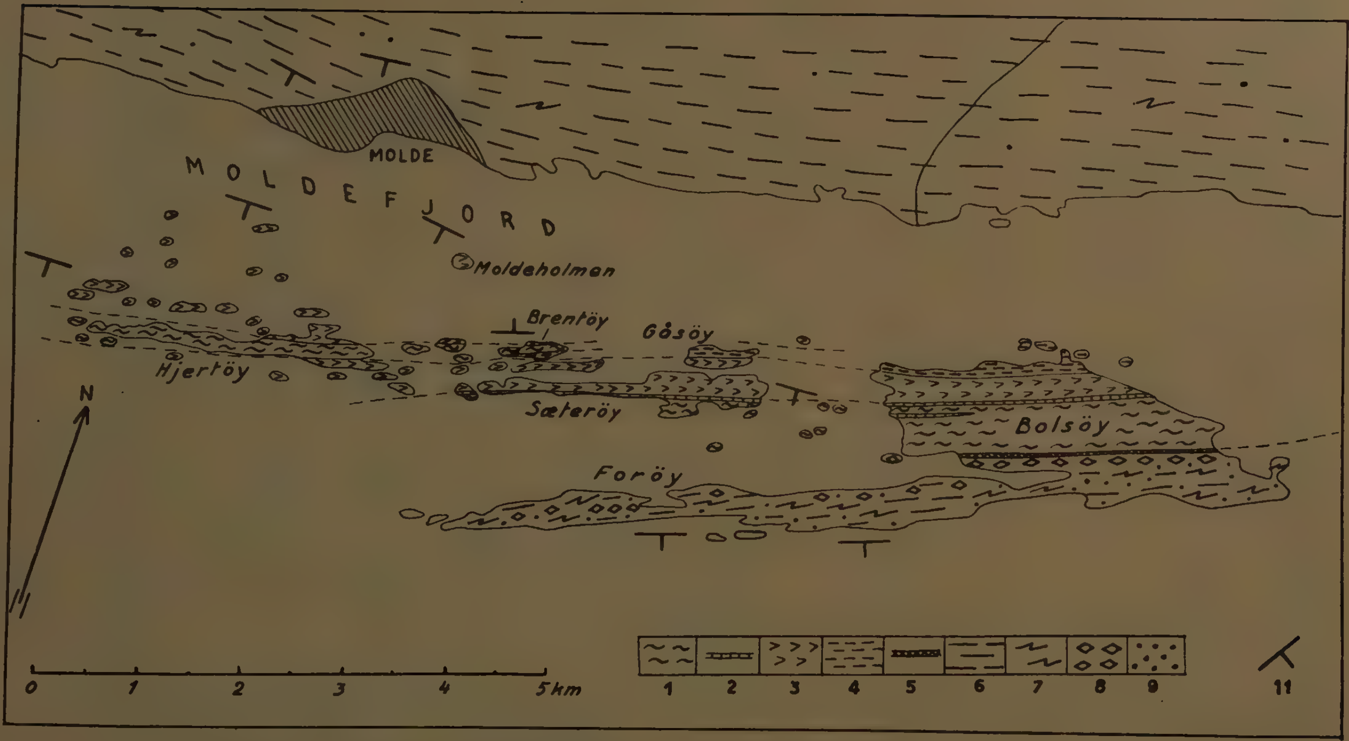


Fig. 2. Geologisk kart over Moldeøyene. *Geological map of the Molde islands.*

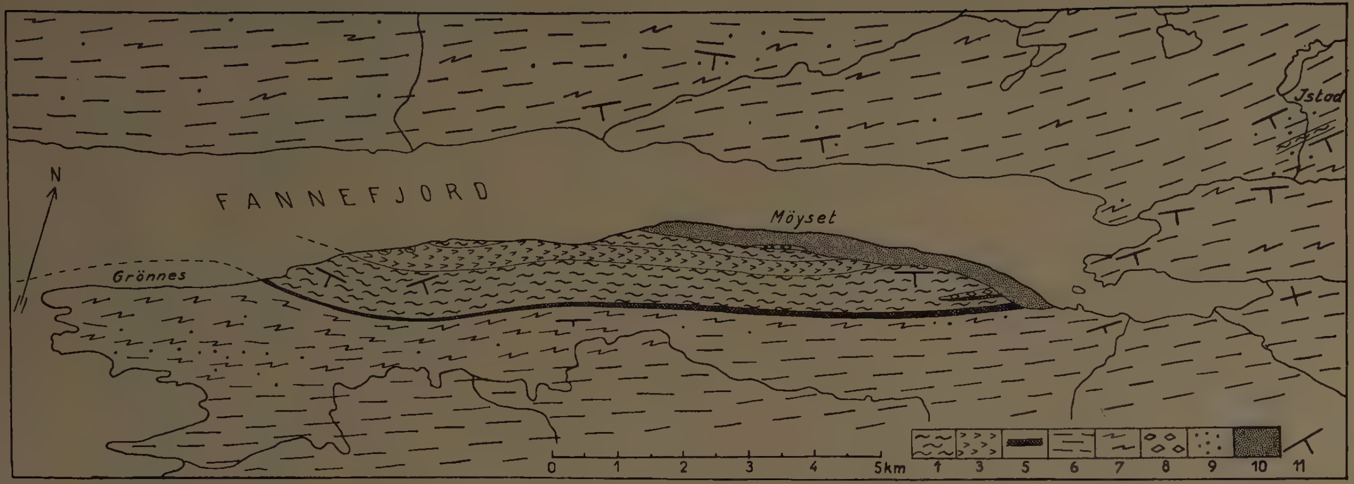


Fig. 3. Geologisk kart over området ved Fannefjorden. *Geological map of the Fannefjord district.*

Tegnforklaring til fig. 2 og 3. Trondhjemsskifre: 1. Glimmerskifer. 2. Kalkstein. 3. Grønnskifer. 4. Hornblendeporfyroblastskifer. 5. Kvartsskifer. Gneiser: 6. Kvartsdioritisk-granodioritisk gneis. 7. Granitisk gneis. 8. Øyegneis. 9. Amfibolit. 10. Løse avleiringer. 11. Foliasjon, strøk og fall.

Legend to figs. 2 and 3. Cambro- Lower Ordovician schists: 1. Mica schist. 2. Limestone. 3. Green schist. 4. Hornblende — biotite schist. 5. Quartz schist. Gneisses: 6. Quartzdioritic-granodioritic gneiss. 7. Granitic gneiss. 8. Augen gneiss. 9. Amphibolite. 10. Quaternary deposits. 11. Foliation, strike and dip.

lengde til den forsvant i fjorden. Dessuten ses en rekke kalkspatårer og kvartsslirer i grønnskiferen.

En sone med hornblendeporfyroblastskifer, og et par soner med glimmerskifer ses i grønnskiferdraget.

Aller nordligst på Bolsøy, nord for grønnskiferen, står hornblendeporfyroblastskifer. Den kan følges vestover langs nordsiden av Gåsøy og sydsiden av Brentøy, hvoretter draget forsvinner.

Den mikroskopiske undersøkelse av hornblendeporfyroblastskiferen viser at den inntar en mellomstilling mellom grønnskifer og glimmerskifer. Ved siden av hornblende og plagioklas inneholder den glimmer og kvarts. Rester av biotit i hornblenden viser at hornblendeporfyroblastene tildels er vokset på bekostning av biotit. Både hornblendens og plagioklasens sammensetning svarer helt til hornblenden og plagioklasen i grønnskiferen, og biotiten til glimmerskiferens biotit, og en kan videre tildels se en svak lagdeling mellom grønnskifermineralene og glimmerskifermineralene i hornblendeporfyroblastskiferen. Det er derfor naturlig å anta at bergarten er dannet av vulkansk materiale, kanskje aske, iblandet vekslende mengder leire.

I den vestlige del av Moldeøyene står et drag med glimmerskifer nord for grønnskiferen, Det danner den sentrale del av Brentøy og Hjertøy, og bygger dessuten opp flere mindre øyer, holmer og skjær. Også i dette glimmerskiferdrag ses soner rike på kvarts og hornblende.

Nordligst består Moldeøyene av tallrike små øyer, holmer og skjær. Området ble undersøkt ved lavvann for å få den best mulige oversikt over utbredelsen av de forskjellige bergarter. Det viser seg at grønnskifer er den dominerende bergart, med enkelte soner med hornblendeglimmerskifer, tildels utviklet som hornblendeporfyroblastskifer. Spesielt på Moldeholmen står meget hornblendeglimmerskifer. Glimmerskifer opptrer helt underordnet. En kan derfor anta at den nordligste del av Moldeøyene hører til et større drag med grønnskifer. I den sydlige del av draget ses to soner med uren kalkstein.

Skifre på sydsiden av Fannefjorden.

Moldeøyenes skifre har en østlig fortsettelse i et drag med trondhjemsskifre på sydsiden av Fannefjorden. Skifrene går i land øst for

Grønnes, og stryker langs fjorden inn til bunnen av denne. Strøket er øst-nordøstlig, fallet sydlig. Fjellgrunnen er her sterkt overdekket. En rekke gårder ligger på glimmerskifer, mens grønnskiferen er skogkledt. Syd for skifrene står gneiser.

Analogt de geologiske forhold på Moldeøyene står her sydligst et drag med glimmerskifer. Langs grensen mellom gneis og glimmerskifer ses også her en smal sone med kvartsskifer. Mektigheten tiltar en del østover. Også her er kvartsskifersonen overalt iakttatt på grensen mellom gneis og glimmerskifer.

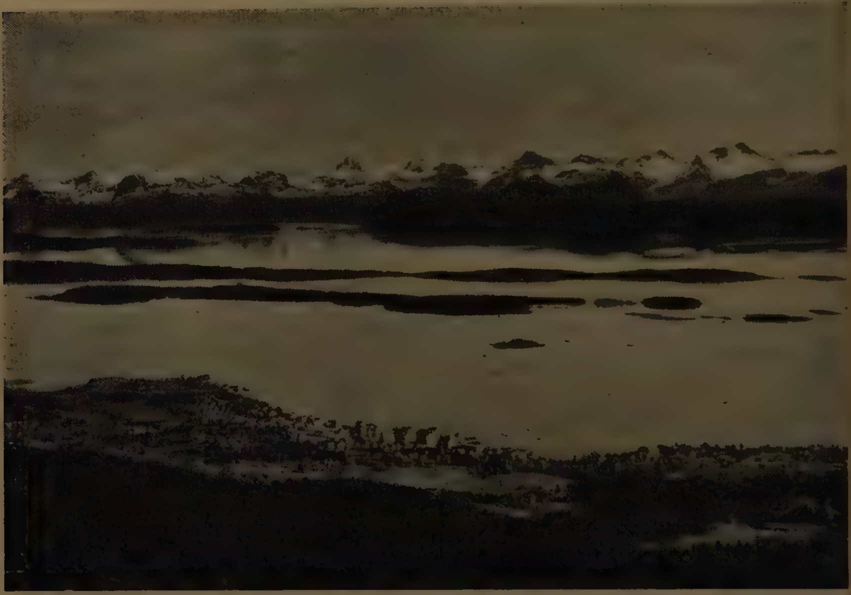
Glimmerskiferen grenser i nord til grønnskifer. Nord for grønnskiferen står igjen glimmerskifer. Glimmerskiferen er tildels granatførende. Grønnskiferen viser epidotisering.

Nord for glimmerskiferdraget er iakttatt et mindre parti med øyegneis ved Møyset. Øyegneis er en typisk grensegneis for skifrene ved Molde, og det er sannsynlig at vi her har skiferområdets nordgrense. Østligst i det sydlige glimmerskiferdrag ses en sone med øyegneis og kvartsskifer.

Videre ses to mindre forekomster med granodioritisk gneis vestligst i grønnskiferdraget. Grenseområdet gneis-grønnskifer er sterkt oppknust, og det er her ganske sikkert sekundære, tektoniske grenser. Ellers ses atskillig oppknuste partier i skifrene syd for Fannefjorden.

For å finne en eventuell fortsettelse av trondhjemsskifrene videre østover ble området like øst for bunnen av Fannefjorden nærmere undersøkt. Fjellgrunnen er også her sterkt overdekket, men det ble funnet så mange mindre partier med gneis, at det ikke kan stå noe større drag med trondhjemsskifre her. Bare ved Istad fant jeg skifre i fast fjell. Her står en ca. 75 m mektig sone med glimmerskifer. Strøket er NO, fallet sydlig.

At det ikke står noe større drag med trondhjemsskifre like øst for Fannefjorden, skyldes at skifrene antakelig kiler ut østover. Dersom øyegneisen ved Møyset markerer skifrenes nordgrense, smalner sonen med trondhjemsskifre av østover. Fallet er i området ved Møyset svakt sydlig, i syd steilt sydlig. Foldningsaksen har vestlig fall både her og på Moldeøyene. Ser man dessuten på topografien må en anta at skifrene har ligget over gneisen som står ved Osen innerst i Fannefjorden. Gneisen her har tilsvarende fall som skifrene.



Fot. E. Birkeland

Fig. 4. Den sentrale del av Moldeøyene. Molde i forgrunnen.
The central part of the Molde islands. Molde in the foreground.

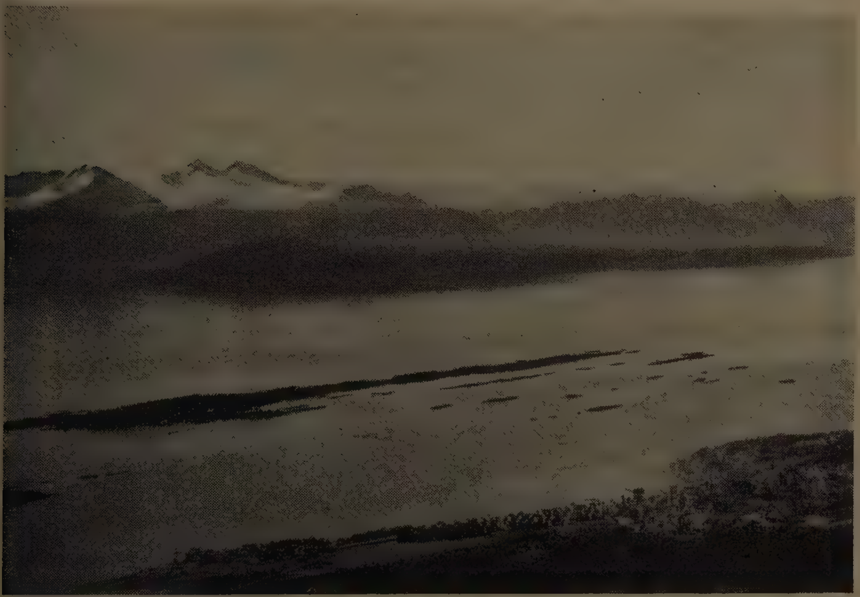
Glimmerskiferen ved Istad ligger nord for det beskrevne drag med trondhjemsskifre, og faller inn under dette.

Grenseområdet gneis — skifer og aldersforhold.

Grensen mellom gneisen og trondhjemsskifrene er fullstendig konkordant. Gneisen nærmest skifrene er utvilsomt foldet samtidig med skifrene, men antakelig har også gneisene i større avstand tatt del i samme foldningsfase.

Det er videre en vakker granitiseringskontakt mellom de to avdelinger. Glimmerskiferen viser en begynnende trondhjemitisering mot gneisgrensen. Karakteren av denne omdannelse er nærmere omtalt i beskrivelsen av Moldeøyenes skifre. En slik trondhjemitisering er ofte den første fase i en fullstendig granitisering.

Gneisen mot skifergrensen viser både feltgeologisk og mikroskopisk en utpreget mikroklinisering. Kvartsdioritiske gneiser viser overgang til granodioritiske og granitiske typer, tildels med store



Fot. Widerøe's Flyveselskap A/S.

Fig. 5. Den vestlige del av Moldeøyene. Molde i forgrunnen.
The western part of the Molde islands. Molde in the foreground.

mikroklinporfyroblaster. Forholdene er best undersøkt på Bolsøy—Forøy. Her opptrer langs grensen en øyegneis med opptil 10 cm store øyne. Det har i grenseområdet foregått en granitisering av plagioklasgneisen, med delvis dannelse av øyegneis.

Både trondhjemitiseringen av glimmerskiferen og granitiseringen av plagioklasgneisen har i første rekke foregått etter skifrighetsflatene, og svakere og sterkere omdannete soner veksler med hverandre.

Etter de feltgeologiske og mikroskopiske undersøkelser må en anta at den granitiserte plagioklasgneis opprinnelig har vært en glimmerskifer. Den har først gjennomgått en trondhjemitisering, som en første fase i en fullstendig granitisering. Som fase nr. 2 er plagioklasgneisen videre omdannet til granitisk gneis.

På Bolsøy og Forøy grenser den granitiserte plagioklasgneis helt i syd til en lysgrå, biotitførende kvartsrik gneis. Vi har her muligens sydgrensen for de opprinnelige trondhjemsskifre.

Kvartsskifersonen langs grensen gneis — glimmerskifer danner overalt et skille mellom den granitiserte plagioklasgneis og den trondhjemitiserte glimmerskifer. Kvartsskiferen har tydelig virket som en mur som overalt har greid å stoppe den videregående granitisering.

Kvartsskifersonen har ifølge denne oppfatning opprinnelig dannet et lag inne i glimmerskiferen. Den kan også bli oppfattet som et basallag for trondhjemsskifrene, men ifølge mine undersøkelser og tilsvarende undersøkelser av STRAND (1953) i Surnadalen må en anta at gneisen mot kvartsskifersonen er granitiserte trondhjemsskifre.

I det granitiserte gneisområde opptrer tallrike inneslutninger av amfibolit. Som nevnt i beskrivelsen av Moldeøyenes skifre er opptreden av amfibolit også karakteristisk for glimmerskiferen mot gneisgrensen. Også gneisområdets amfiboliter må oppfattes som metamorfe intrusiver. Gneisområdets og glimmerskiferens amfiboliter antas å være en og samme dannelse som er trengt frem i den svakhetssone som grenseområdet har representert.

Skifrene på Moldeøyene og langs sydsiden av Fannefjorden svarer til Trondhjemsfeltets skifre, og er en fortsettelse av Surnadalssynklinalen i Trondhjemsfeltet. Det er videre sannsynlig at både det sydlige og det nordlige glimmerskiferdrag svarer til Rørosgruppen, som er av kambrisk til lav underordovicisk alder, og at grønnskiferdragene svarer til den underordoviciske Bymark—Størengruppe. Det sentrale glimmerskiferdrag på Moldeøyene antas å være en avsetning i Bymark—Støren formasjonen. Alderen av skifrene ved Molde er da kambro-underordovicium.

Foldningen av skifrene, trondhjemitiseringen av glimmerskiferen og den videregående granitisering av plagioklasgneisen må være av kaledonsk alder.

Petrografi.

Glimmerskifer.

Mengdeforholdet mellom de enkelte mineraler i glimmerskiferen varierer atskillig. Som et middel kan en sette opp følgende mineralinnhold, i volumprosent: Kvarts 45 %, plagioklas 18 %, epidot 2 %, biotit 33 %, granat 2 %. I en enkelt prøve opptrer rikelig med muskovit sammen med biotit. Aksessoriske mineraler er hornblende, kis, jernerts, turmalin, apatit og kalskpat.

Kvartsen viser som regel undulerende utslukning.

Plagioklasens sammensetning varierer fra kalkrik oligoklas til natronrik andesin. Tvillinger etter albitloven er alminnelig, periklintvillinger er sjeldne. Plagioklas i glimmerskifer fra Sæterøy viser følgende optiske forhold: 2V ≈ 90°. Ng = 1.554, Nm = 1.551, Np = 1.547, målt i pulverpreparat. Feilgrense ± 0.002. Ng ÷ Np = 0.007. Dette svarer til en andesin med $Ab_{65}An_{35}$ (WINCHELL 1945).

Biotitens pleokroisme er lys gul - brun.

Granatene danner porfyroblaster i skiferen. De holder tallrike små inneslutninger, vesentlig kvarts. Disse inneslutninger er tildels ordnet i hvirvler, en form som har sin grunn i rotasjon under granatens vekst.

Granatene er isotrope. Megaskopisk farge er brunrød, mikroskopisk farge er rødbrun. Granat i glimmerskifer fra Sæterøy viser følgende konstanter: Sp. v. = 4.00, bestemt med pycnometer og Clericis veske. Resultatet er korrigert m.h.t. små inneslutninger av kvarts. N_{Na} = 1.793 ± 0.002, målt i pulverpreparat. Dette gir en granat med 17 % grossular, 66 % almandin og 17 % pyrop (WINCHELL 1945).

Grønnskifer og hornblendeporfyroblastskifer.

Grønnskiferen viser praktisk talt ingen mineralogisk variasjon. Mineralinnholdet er, i volumprosent: Hornblende 85 %—90 %, plagioklas 10 %—15 %. Aksessorisk opptrer kvarts, epidot, kis (svovelkis), jernerts og kalkspat.

Hornblenden viser følgende optiske forhold: ÷ 2V = ca. 70 °. $Z \wedge c = 21°$. Pleokroisme : X = gul, Y = grønn, Z = blågrønn. Absorpsjon : $X < Y < Z$. Dette svarer til en alminnelig grønn hornblende.

Plagioklasens sammensetning ble bestemt med maksimale utslukningsvinkler i snitt $\perp$ 010, $X' \wedge 010$ (WINCHELL 1945). Det ble målt andesin med $Ab_{60}An_{40}$.

Hornblendeporfyroblastskiferen inntar en mellomstilling mellom grønnskifer og glimmerskifer. Hovedmineraler er kvarts, plagioklas, biotit og hornblende. Dessuten ses klorit som omdannelsesprodukt av biotit, og i et par prøver ses en del tremolit. Aksessorisk opptrer epidot, granat, kis, jernerts og apatit.

Det er bestemt plagioklas med $Ab_{60}An_{40}$, altså en tilsvarende andesin som i grønnskiferen. Hornblenden svarer også til hornblenden i grønnskiferen. Biotiten har en tilsvarende pleokroisme som i glimmerskiferen.

Kalkstein.

Kalksteinen består vesentlig av kalkspat. Det er ikke utviklet noe reaksjonsskarn mot grensebergartene.

Følgende mineraler er funnet i kalksteinen, alle i kontakt med kalkspat: Kvarts, plagioklas, epidot, flogopit, biotit, hornblende, jernerts, rutil, grønn spinell og turmalin. Hornblenden minner meget om hornblenden i grønnskiferen og hornblendeporfyroblastskiferen men har blekere farger.

ENGLISH SUMMARY

Cambro - Lower Ordovician schists are found on the Molde islands and along the south side of Fannefjord, forming a syncline in the North-Western Gneiss Area of Southern Norway. The schists are followed west by Bugge (1935) and Gjelsvik (1951, 1953) and the syncline is thought to form an extension to the west-south-west of the Surnadal syncline of the Trondhjem Region.

The syncline is composed chiefly of mica schist and green schist, with hornblende-biotite schist occurring to a lesser degree. The mica schist contains some narrow zones of limestone and quartzite.

The green schist is assumed from its composition and geological appearance to be altered basaltic lavas. The hornblende-biotite schist is presumed to have originated from volcanic material admixed with varying amounts of clay.

The boundary between the schist and the surrounding gneiss is entirely concordant. There is further a striking granitization contact between the two divisions. The mica schist shows an incipient trondhjemitization at the gneiss boundary, as a first phase in a complete granitization. The gneiss at the boundary is presumed to have originated from a mica schist belonging to the Cambro - Lower Ordovi-

cian schists, through a trondhjemitization and a subsequent granitization process. A narrow zone of quartz schist is everywhere found between the granitized and the trondhjemitized mica schist. The quartz schist has functioned as a wall which has everywhere prevented a further granitization.

Both the trondhjemitized and the granitized mica schist contains numerous inclusions of amphibolite. These are interpreted as metamorphic intrusives which have advanced in the weak boundary zone.

The folding of the schists, and the trondhjemitization and the granitization of the mica schist are of Caledonian age.

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THE CYPRIN—THULITE DEPOSIT AT ØVSTEBØ, NEAR KLEPPAN IN SAULAND, TELEMARK, NORWAY

BY

HENRICH NEUMANN AND SVERRE SVINNDAL

Introduction

The deposit to be discussed in the present paper is situated as shown in Figs. 1 and 2 near the farm Øvstebø not far from Kleppan in the district of Sauland in the county of Telemark in Southern Norway. The locality has earlier been given partly as Kleppan and partly as Sauland or Souland (old spelling). It is the type locality for cyprin (blue var. of vesuvianite) which was described by BERZELIUS in 1820, and for thulite (red var. of zoisite) described by BROOKE in 1823. The first to publish any information about the deposit as such was Scheerer in 1845; BRØGGER gives a crystallographic description of thulite in 1879, and WERENSKIOLD has a sketch map and a profile of the Øvstebø deposit in his paper on the geology of Eastern Telemark in 1909 (p. 51).

Geology.

The district of Sauland is part of the huge area in Southern Norway made up of the Precambrian supracrustal rocks of the Telemark formation: acid lavas (quartz porphyries and rhyolites), basic lavas, tuffs, agglomerates, quartzites, and arkoses. These rocks have been intruded by gabbroic sheets, which are now found as amphibolites usually concordant to the supracrustal rocks, and it may in individual cases be difficult to decide if they are intrusive or extrusive.

The whole rock series has been strongly folded as shown in Fig. 2. The Gausta syncline and the Bleka anticline have been mapped in detail during recent years but the results have not been published so far. The detailed mapping has not reached the district of Sauland but the architecture is most probably in its broad features as shown in Fig. 2.

The rocks of the Telemark formation have to a great extent been granitized, and are, where they are not cut off by faults or disappear under the Caledonides, surrounded by — and are certainly underlain by — the younger Telemark granite (or Telemark gneiss). They are nearly everywhere metamorphosed, in the amphibolite facies close to the Telemark granite, and further away from the granite in the epidote-amphibolite facies or in the greenschist facies. In the Øvstebø—Kleppan area the rocks are found in the epidote-amphibolite facies.

Fig. 3 is a sketch map of the geology of the immediate surroundings of Øvstebø. The strike varies somewhat but averages N 70° W with a steep northerly dip. The predominating rocks are quartz porphyry and agglomerate. The quartz porphyry is light gray with phenocrysts of quartz and feldspar, mainly albite. The phenocrysts are about 1 mm across, while the groundmass is very finegrained, usually with submicroscopic grains, indicating that the porphyry was originally a glassy rock. Sericite and epidote as alteration products are common constituents of the quartz porphyry.

The agglomerate is made up of bigger and smaller angular lava fragments in a very fine-grained groundmass, and has often a green colour because of epidotization. Small blebs and masses of red calcite are quite common and widespread in this rock. North of Øvstebø the agglomerate attains an apparent width of at least 1 000 m. Stratigraphically it corresponds most probably to the zone of tuffs and agglomerates described by D. Wyckoff (1933) from Gausta and Rjukan waterfall.

A number of amphibolites in the surroundings are all concordant to the supracrustal rocks. On the basis of the results of the detailed

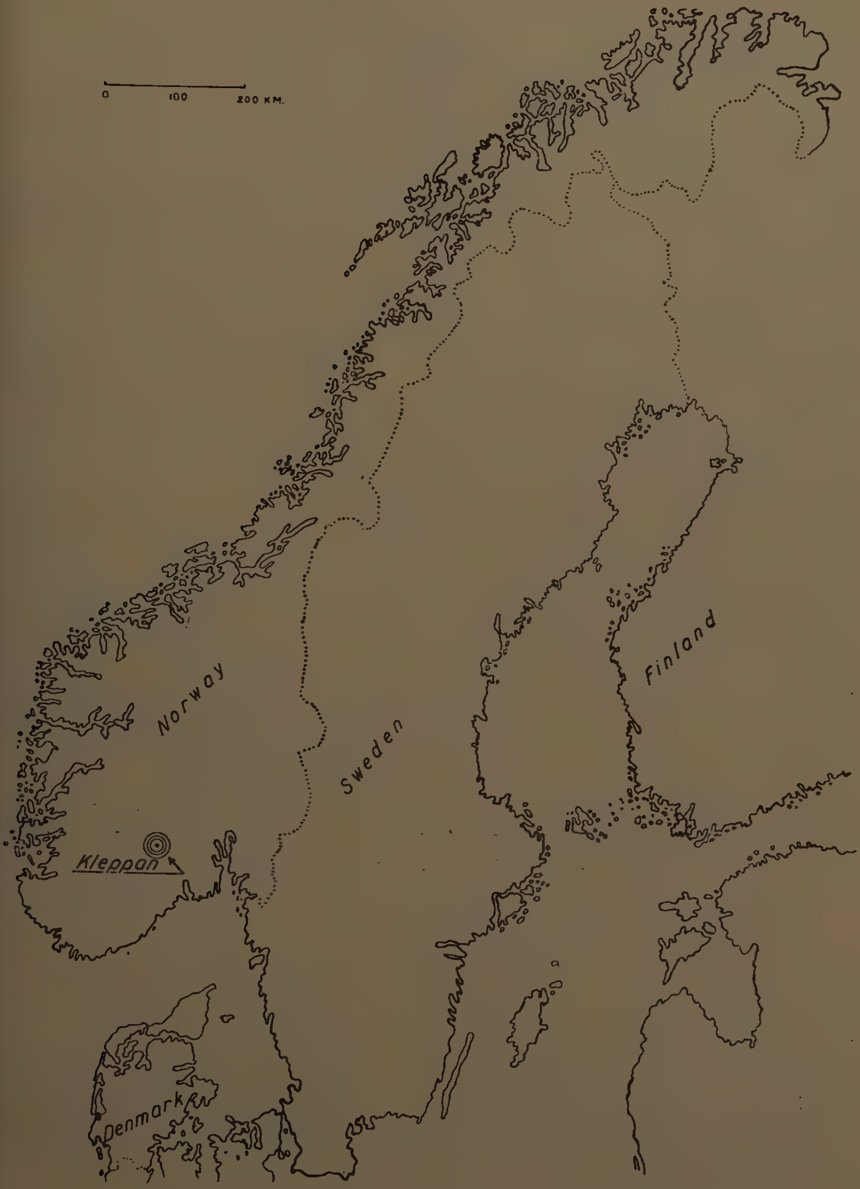

Fig. 1. Map showing situation of Kleppan.

mapping of the Bleka anticline and in the Gausta area they should most probably be interpreted as metamorphosed basic intrusives and not as original lavas. The amphibolites are medium grained, and consist of amphibole, albite, and epidote-clinozoisite.

Pegmatite dykes are not uncommon in this area. They contain feldspar, quartz, and mica, and so far only hematite and epidote have been found as accessory minerals. As seen in Figs. 3 and 4 one of them cuts the cyprin- and thulite-bearing quartz vein.

The nearest exposures of granite are quite a distance from Øvstebø, as shown in Fig. 2. It is of course impossible to make any definite statement about the distance to the underlying granite. The grade of metamorphism, however, indicates that the granite is not too close to the present surfaces.

The mineral assembly or parts of the complete assembly to be discussed in this paper is found in 6 places. The localities are indicated in Fig. 3, and will be referred to as numbers 1—6.

No. 1 is the main occurrence of cyprin, thulite, etc., and is the one which has been known for a long time, while the other minor ones have been found during the course of the present investigations. A sketch map of the deposit is presented as Fig. 4. The big quartz vein which forms deposit No. 1 is emplaced parallel to the strike of the country rocks, and contains all the minerals to be described below with the exception of tremolite. Some blasting has been done, probably in search of valuable minerals, in two places indicated by O in Fig. 4. The bedrock is unfortunately widely covered by drift, impeding a detailed investigation of structural relationships. A possible zoning of the vein, for example, may have escaped observation.

At localities 2 and 3 a number of quartz lenses are found, which may attain a length of 1 meter or more. Locally they contain thulite, cyprin, tremolite and calcite. The bedrock is an epidotized agglomerate with a somewhat variable strike about NNW and with an easterly dip of about 45°. Small pegmatite veins or lumps are common; they are mostly emplaced parallel to the schistosity of the agglomerate but crosscutting structures are not unusual. A sketch from No. 3 is presented as Fig. 5.

At the place marked No. 4 on the map the agglomerate is coloured red over a small area by an impregnation of thulite. Quartz has been

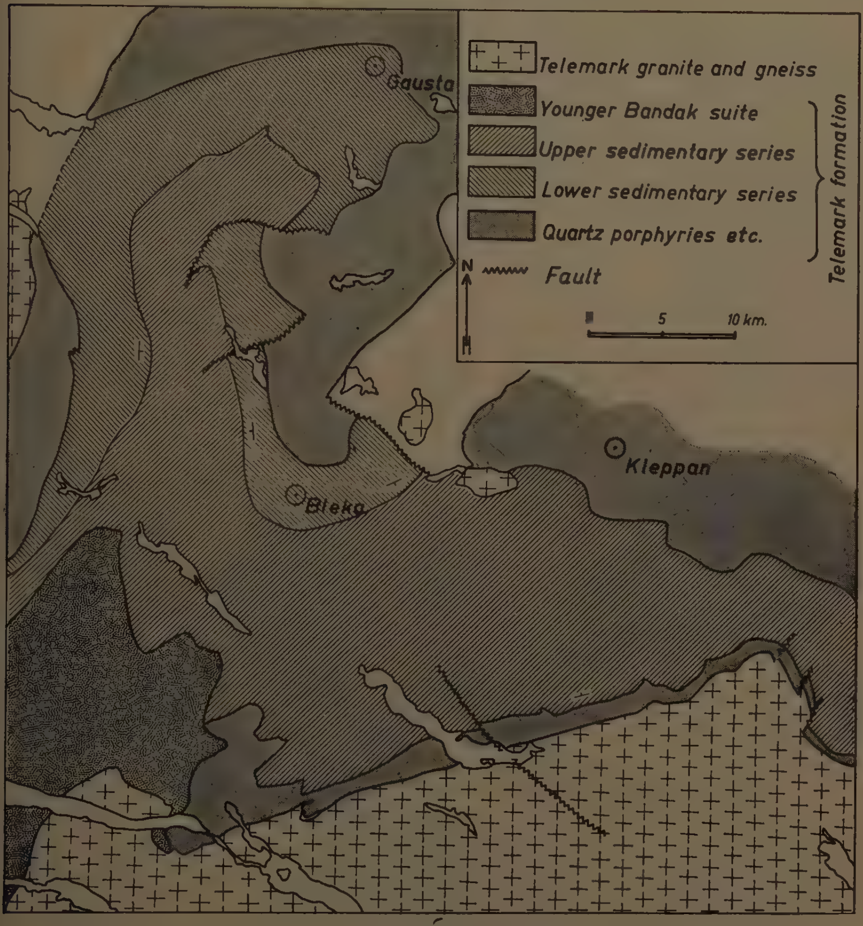

Fig. 2. Geological map of a part of the Telemark formation.

introduced at the same time, but true quartz masses have not been formed.

Deposit No. 5 is a quartz vein or elongated lens of quartz quite rich in tremolite and scapolite, and with some thulite. Cyprin has not been found in this vein.

At locality No. 6 cyprin, thulite, and grossularite together with quartz are found in cavities in amphibolite close to its contact with quartz porphyry.

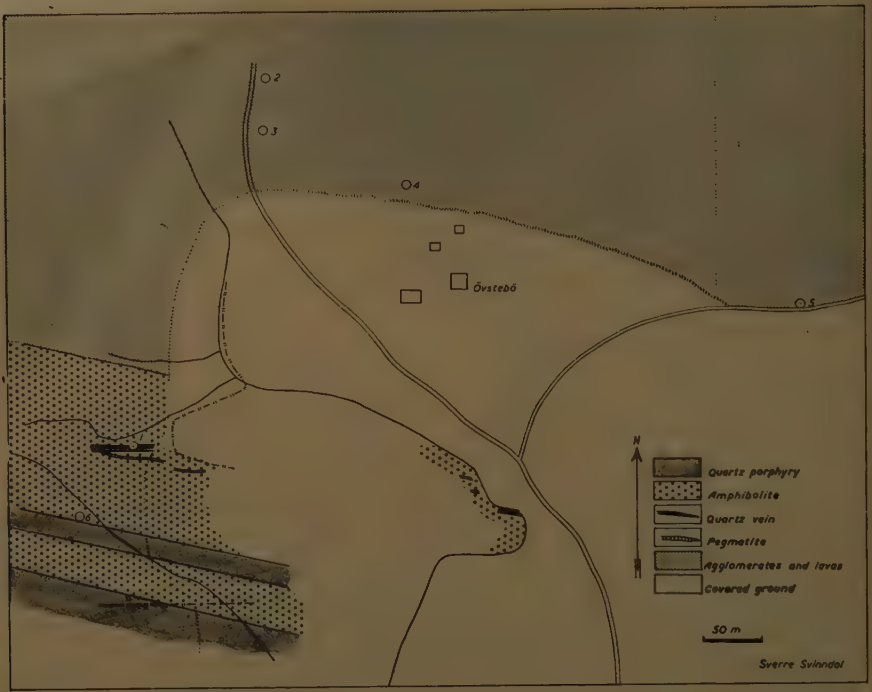

Fig. 3. Geological map of the surroundings of Øvstebø near Kleppan. The mineral occurrences discussed in the text are numbered from No. 1 to No. 6.

It is worthy of notice that the cyprin — thulite — etc. paragenesis is found in different kinds of bedrock, in No.'s 2, 3, 4, and 5 in quartz porphyry, in No. 6 in amphibolite, and in No. 1 on the contact between amphibolite and quartz porphyry.

Description of the minerals.

Fluorite.

Fluorite is quite common. It varies in colour from colourless to a deep blue. An optical spectrogram showed nothing of interest apart from some Mg and traces of Fe and Mn which may be due to impurities.

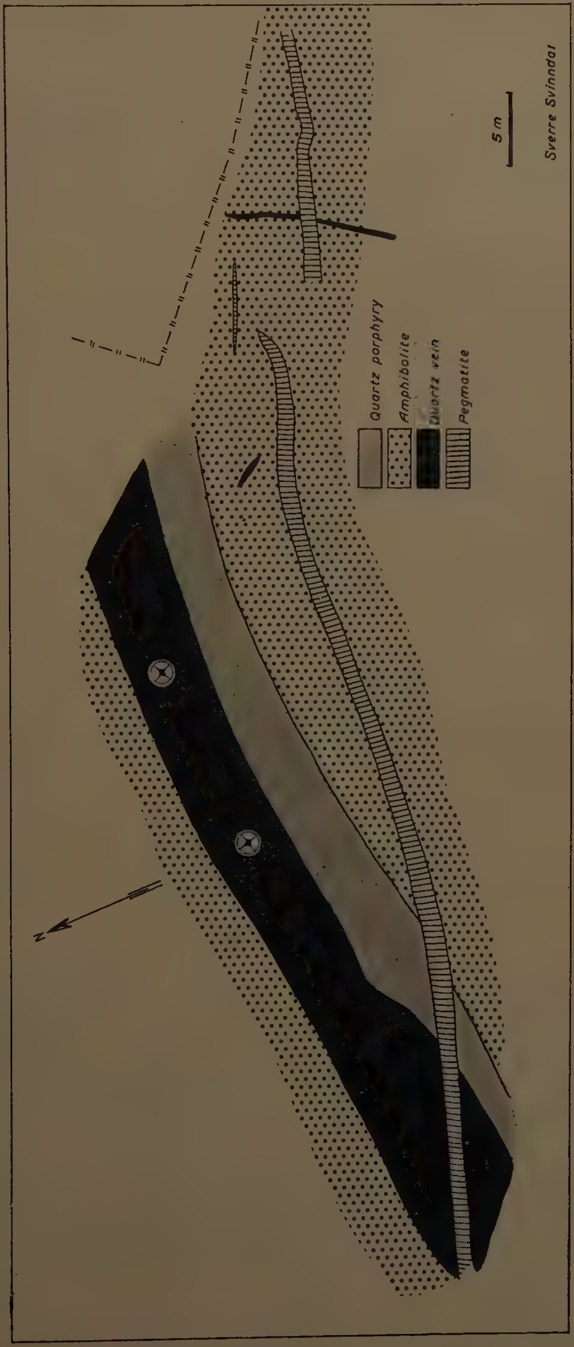

Fig. 4. Detailed geological map of the main cyprin-thulite occurrence. (No. 1 of Fig. 3).

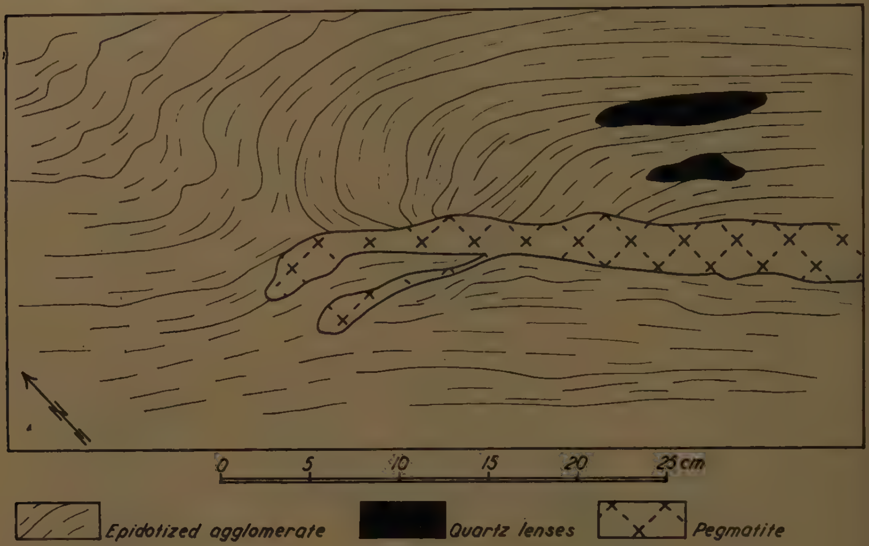

Fig. 5. Sketch map from cyprin — thulite occurrence No. 3. (See fig. 3).

Hematite.

Hematite is the only opaque mineral found in Sauland so far. It is not very common, but is found now and again together with and in the same way as the other minerals.

Quartz.

Quartz is the dominating mineral in all deposits, occurring to the extent of at least 80 percent. An optical spectrogram shows traces of aluminium.

Calcite.

Calcite is quite common, but is probably less common than fluorite, and very subordinate compared to quartz. An optical spectrogram taken by Mr. S. Rutlin shows some magnesium but no traces of rare earth elements.

Scheelite.

Scheelite has so far been found in a few specimens only from deposit No. 1. It occurs intimately associated with quartz, thulite, epidote, cyprin, grossularite, fluorite, calcite and desmin. The fluorescence colour in short wavelength ultraviolet light is a pure white, perhaps with a slight tinge of yellow, indicating a content of about 0.7 percent molybdenum (HORNE 1951). An optical spectrogram shows in addition to Ca, Wo, and Mo traces of Al and Be. To the authors' knowledge Be has not earlier been reported in scheelite.

Grossularite garnet.

Grossularite is of common occurrence in the association grossularite, cyprin, thulite, fluorite, quartz. The colour varies from a pure white to a very light greenish yellow or brownish yellow. The crystals which can attain a size of one cm across are bounded by (110), with occasional development of (100) faces.

The chemical composition is shown in table No. 1. A calculation of the analysis on the basis of twelve O's gives the following formula:

$(Ca_{2.928}\ Mg_{0.022}\ Mn_{0.056}\ Fe_{0.006}\ Na_{0.003}\ K_{0.002})$

$Al_{2.128}\ (Si_{2.776}\ H_{0.482})\ O_{12}$

which, if Mg, Mn, Fe, Na, and K is replaced by Ca, and 4 H by Si is

$Ca_{3.0}\ Al_{2.1}\ Si_{2.9}\ O_{12}$,

in close agreement with the ideal formula of grossularite, $Ca_3\ Al_2\ Si_3\ O_{12}$.

In terms of molecular percent of the pure garnet «molecules» the composition is:

93.2 mol percent grossularite.
4.0 — tricalcium aluminate hexahydrate.
1.9 — spessartite.
0.7 — pyrope.
0.2 — almandine.

The edge length (a) of the unit cell was determined and found to be 11.855±0.010 Å. As first pointed out by STOCKWELL (1927) and later confirmed by others a linear relationship exists between edge lengths and chemical composition within the garnet group (a slight deviation in the hydrogrossularite series has been demonstrated by YODER (1950)). After minor corrections for the content of the other garnet «molecules» in the Sauland grossularite the edge length of pure grossularite is calculated to

$$a = 11.835 \pm 0.010 \text{ Å}.$$

The specific gravity of the analyzed material is 3.567. If this value is adjusted in the same way as above, the specific gravity of pure grossularite is calculated to

$$\text{sp.g.} = 3.598.$$

The specific gravity calculated from the above value of *a* is for pure grossularite

$$\text{sp. g.}_{\text{calc.}} = 3.584.$$

The refractive index is $n_{Na} = 1.719 \pm 0.002$ which recalculated as above gives a value for pure grossularite of

$$n = 1.722 \pm 0.002$$

a value which is about 0.02 lower than what would be expected from data published earlier (H. S. YODER, 1950).

An optical spectrogram taken by Mr. S. RUTLIN shows lines of Ti, V and Ga in addition to the major components. The V content was roughly estimated by Mr. RUTLIN to O.x percent which is a surprisingly high figure for a grossularite.

Colour and refractive index vary considerably from specimen to specimen and from crystal to crystal. A pure white grossularite gave $n = 1.727 \pm 0.002$, and a yellow variety from the same specimen $n = 1.733 \pm 0.001$.

Epidote (*Clinozoisite*).

Epidote occurs in a somewhat different way from the other minerals, as it is usually found in lumps and variously shaped finely crystalline masses which are probably formed by replacement of inclusions of wallrock. More often than not they are surrounded by a not too well defined rim of grossularite varying in width from zero to two centimeters.

The colour of the Sauland epidote varies from a light green to a fairly dark green.

Piedmontite (*Manganiferous clinozoisite*).

Piedmontite has been identified by its characteristic colour and x-ray powder pattern. It resembles thulite but is more brownish red, as opposed to thulite's pink to rose red. It occurs together with, and in the same way as, thulite, but is less common.

Thulite (*Pink zoisite*).

Thulite of a lively pink to rose colour is common in the association thulite — grossularite — cyprin — quartz — calcite — fluorite. It is mostly massive but good crystals are also found; in fact W. C. BRØGGER (1879) determined the axial ratios and solved the problems of the crystallography of zoisite on perfect crystals of thulite from Sauland.

The chemical composition is given in table No. 1. The amount of manganese is surprisingly low. It is nevertheless believed that trivalent manganese is the cause of the pink colour. No attempt has been made to actually determine by experiment the valence state of this element because of the experimental difficulties involved, the content of Mn_2O_3 being only 0.34 percent and with divalent as well as trivalent iron present in the same mineral.

A calculation of the analysis on the basis of 13 oxygen atoms gives the following result $Ca_{2.00}\ Al_{2.84}\ Fe^{III}_{0.18}\ Mn^{III}_{0.02}\ Fe^{II}_{0.08}\ Si_{2.97}\ O_{13}\ H_{0.86}$. On the assumption that Fe and Mn replace Al this gives the formula

$$Ca_{2.0}\ Al_{3.1}\ Si_{3.0}\ O_{13}\ H_{0.9}$$

in fair agreement with the theoretical formula.

The specific gravity of the analyzed material is 3.38, and the refractive indices $\alpha_{Na} = 1.700 \pm 0.001$, $\beta_{Na} = 1.703 \pm 0.001$, and $\gamma_{Na} = 1.708 \pm 0.002$. The mineral is biaxial positive with $+ 2V = 71° \pm 1°$, and is a β-zoisite with the optic plane normal to (010). It is somewhat surprising that the Sauland thulite with an iron-content of only 3.06 percent Fe_2O_3 is β-zoisite, and with an axial angle as high as 71°.

The physical properties vary considerably from specimen to specimen. The data given above are determined on the analyzed material, which, to ascertain homogenity, was produced from a number of large crystals from one and the same specimen by a heavy liquid separation.

Cyprin (*Blue vesuvianite*).

Cyprin is of common occurrence in the association cyprin-thulite-grossularite-quartz-calcite-fluorite. It is usually well crystallized but is very easily broken and good crystals are therefore difficult to obtain. The colour is a deep sky-blue, but varieties which are greenish blue to bluish green are very common. The name cyprin was given to the Sauland vesuvianite by J. J. Berzelius (1820) in allusion to its blue colour. He proved the presence of copper by a blowpipe analysis and ascribed the blue colour to the presence of that element.

An analysis of cyprin is given in Table No. 1. Warren and Modell (1931) give the following general formula of vesuvianite $Ca_{10}Al_4(Mg, Fe)_2Si_9O_{34}(OH)_4$, and point out that there are two sets of tetrahedral positions in the structure, usually empty, one of which is probably responsible for the accomodation of the occasional content of Be in vesuvianite. Machatschki (1932) has remarked that one of the 10 Ca ions has a unique position, which is really somewhat too restricted for the big Ca ions, and he gives evidence for a tendency towards accomodation of the smaller Mg ions in this position. Taking Machatschki's remarks into consideration, the formula may be rewritten in the following way:

$$X_9(X, Y)Y_4Y_{2-x}E_xZ_9(O, OH, F)_{38}$$

where X stands for the big ions (Ca, Na, K), Y for the medium sized ions (Mg, Mn, Fe, Al), Z for Si (which can, to some extent, be replaced by Al), and E for ions in one of the two sets of usually empty tetrahedral positions.

A calculation of the analysis on the basis of 38 ozygens gives the following result:

$(Ca_{8.908}\ Na_{0.092})\ Ca_{0.229}\ Mn_{0.121}\ Fe_{0.291}\ Mg_{0.359})\ Al_{4.0}\ (Al_{1.102}\ Mg_{0.442}\ Ti_{0.072})\ (Be_{0.172}\ Cu_{0.144})\ (Si_{8.792}\ Al_{0.208})\ (O_{34.632}\ OH_{2.238}\ F_{1.130})$, or $X_9(X,Y)Y_4Y_{2-0.40}\ E_{0.32}\ Z_9(O, OH, F)_{38}$, a result which is very close to the crystallographically established formula.

Cu has tentatively been placed with Be in the vacant tetrahedral positions. The content of Cu is too low to make possible a direct location of that element.

The specific gravity of the analyzed material is 3.421, in good agreement with data published elsewhere.

The mineral is uniaxial negative with

$$\omega_{Na} = 1.705 \pm 0.002 \text{ and } \varepsilon_{Na} = 1.697 \pm 0.002.$$

The values given by Larsen (1934) for cyprin are higher by 0.008.

Diopside.

Diopside is very rare, and has so far been found in one specimen only from the upper trial in deposit No. 1, where it occurs associated with epidote, thulite, cyprin, and grossularite. The colour is a pure white, perhaps with a slight tinge of yellow. The mineral gives the characteristic x-ray powder pattern of the diopside-hedenbergite series. It is biaxial positive with $\alpha_{Na} = 1.671 \pm 0.003$, $\beta_{Na} = 1.679 \pm 0.002$, and. $\gamma_{Na} = 1.702 \pm 0.003$. The specific gravity is 3.30 ± 0.01. These data are characteristic of a diopside with an approximate composition $Di_{90}He_{10}$.

Tremolite.

Tremolite is rather rare. It occurs in white needles together with scapolite in deposit No. 5, and was identified by its characteristic x-ray powder pattern. A green variety, apparently a more iron-rich member of the tremolite-actinolite series is found in quartz in deposit No. 1.

Oligoclase.

Feldspar is quite rare in the Sauland deposits. A specimen from deposit No. 1 has stringers and blebs of oligoclase in quartz, with $\alpha_{Na} = 1.542 \pm 0.002$, $\beta = 1.546 \pm 0.001$, $\gamma = 1.550 \pm 0.002$, and 2 V — was estimated to 85°. The optic data correspond to an oligoclase of composition Ab_{74} An_{26}.

Scapolite.

Scapolite is of rare occurrence and is found in any amount only in deposit No. 5, where it occurs intimately associated with thulite. It is uniaxial negative with high birefringence and $\omega = 1.592 \pm 0.001$, corresponding to a calcium-rich scapolite of composition Me_{77} Ma_{23}.

Desmin.

Desmin is rare and has been found in deposit No. 1 only. It occurs in radiating bundles of pure white needles, associated with thulite and cyprin and in one specimen also with scheelite. $\beta_{Na} = 1.497$, and the identification was confirmed by an x-ray powder pattern.

Paragenesis.

A complete list of the minerals found at Sauland is given below. The formulae are somewhat simplified, taking into consideration only the major chemical components.

Quartz SiO_2
Thulite $Ca_2Al_3Si_3O_{12}OH$
Epidote —»—
Piedmontite —»—
Grossularite $Ca_3Al_2Si_3O_{12}$
Cyprin $Ca_{10}Al_4Mg_2Si_9O_{34}(OH)_4$
Diopside $CaMgSi_2O_6$
Tremolite $Ca_2Mg_5Si_8O_{22}(OH)_2$
Scapolite $Ca_4Al_6Si_6O_{24}CO_3$
Oligoclase $(Na, Ca)Al\ (Si, Al)_3O_8$
Desmin $Ca_2NaAl_5Si_{13}O_{36} \cdot 14H_2O$
Hematite Fe_2O_3
Calcite $CaCO_3$
Fluorite CaF_2
Scheelite $CaWO_4$

Quartz represents the bulk of the deposit. The next most common minerals are thulite, epidote, piedmontite, grossularite and cyprin, followed closely by fluorite. Calcite is subordinate compared to fluorite, and the other minerals are even less common than calcite.

As demonstrated by the list above we are dealing with an assembly of calcium minerals rich in aluminium, and with some magnesium. During the formation of the minerals SiO_2 and probably also H_2O were present in excess. The mineralizing medium also contained appreciable amounts of fluorine and some carbon dioxide.

If the deposit be considered from the point of view of the phase rule, the number of phases are 14. Epidote and piedmontite are counted as one phase only as they are really one species, the only difference between them being a lower or higher content of manganese. The chemical components are

$$SiO_2\ CaO\ MgO\ Na_2O\ Al_2O_3\ Fe_2O_3\ CO_2\ F \text{ and } WO_3.$$

OH has not been counted as a component because the minerals have most probably been in equilibrium with H_2O during their formation, manganese has not been counted as it plays no independent role in the formation of any of the minerals, but replaces aluminium or calcium. A possible content of C1 in the scapolite has not been taken into consideration, as the scapolite is a carbonate scapolite quite close to mejonite in composition. The number of components is therefore 9, and we find in this mineral assembly 14 phases and 9 components in contradiction to the mineralogical phase rule which states that in any mineral deposit in equilibrium the number of phases equals the number of components. The deposit as a unit was therefore not in equilibrium during its formation, a statement which may be put in a different way, namely that the deposit during its formation did not consist of one single chemical system but of a number of chemical systems.

The chemical components may be paired off with the occurring minerals as follows

SiO_2	Quartz
CO_2	Calcite
F	Fluorite.
WO_3	Scheelite
Fe_2O_3	Hematite
Na_2O	Oligoclase and Desmin.
CaO MgO $A1_2O_3$	Thulite, Epidote, Grossularite, Cyprin, Diopside, Tremolite, and Scapolite.

The two sodium minerals oligoclase and desmin never occur in one and the same specimen. In accord with the above statement conditions have apparently been such that in some parts of the deposit oligoclase has been the stable sodium mineral, in other parts desmin.

The three components CaO MgO and $A1_2O_3$ are responsible for the existence of 7 minerals. Of these thulite, epidote (or piedmontite), grossularite and cyprin very commonly occur in intimate association. The curious coexistence of zoisite and clinozoisite (thulite and epidote) was noted already by W. C. BRØGGER (1879). When either tremolite or scapolite is present one of the above mentioned minerals always seems to be absent. In deposit No. 5 where tremolite and scapolite occur together neither cyprin nor grossularite have been found.

As mentioned in the descriptive part of this paper most of the minerals vary considerably in physical properties and chemical composition from specimen to specimen and even from crystal to crystal. This phenomenon is just as much a proof of nonequilibrium conditions during the formation of the deposit as the existence of super-numerary phases.

Genesis.

The mineral assembly found in Sauland would be characteristic for a contact-metasomatic impure limestone in the inner contact zone. Such a mode of formation is, however, out of the question in this case. There is no trace of limestone in the bedrocks, in fact the complete absence of limestone layers is typical for the supracrustal rocks of the Telemark formation (apart from a thin limestone in the younger Bandak suite of rocks, but that is irrelevant to the present problem). Also, there is no granite or other plutonic rock in the immediate neighbourhood, nor are there any indications of a granite close by in depth.

The predominance of quartz together with fluorite and some calcite would be quite normal in a hydrothermal vein. The complete mineral paragnesis, however, and especially the existence of minerals like scapolite, diopside, tremolite, and vesuvianite render impossible the interpretation of the deposit as a hydrothermal vein in the conventional sense of this term.

As discussed above the deposit is in a state of non-equilibrium, a phenomenon which must be accounted for by its mode of formation. The PTX conditions must have been different in different parts of the deposit when the several minerals were formed. A difference in pressure or temperature in this small-sized deposit would necessarily imply a difference in time, and hence the existence of several generations of minerals. There are no signs of that at all; on the contrary, structural and textural observations indicate that all minerals were formed contemporaneously. We are, therefore, compelled to accept a difference in the chemical composition in different parts of the deposit at the time of formation. Such a state of affairs can be explained if the mineral assembly under discussion be interpreted as the products

Table 1. *Analyses in weight percent of minerals from the Øvstebø deposit. A: Thulite. Analyst* Br. Bruun. *B: Grossularite. Analyst* Br. Bruun. *C: Cyprin. Analyst* Br. Bruun. *D: Cyprin. Analyst* G. Lindstrøm (1888).

	A	B	C	D
SiO_2	38.46	37.20	36.9	37.90
TiO_2	tr.	—	0.4	0.26
Al_2O_3	31.20	24.21	18.9	19.47
Fe_2O_3	3.06	0.09	1.1	0.40
FeO	1.25			0.21
MnO		0.88	0.6	0.91
Mn_2O_3	0.34			
MgO	0.01	0.20	2.2	2.17
CaO	24.17	36.65	35.8	36.06
Na_2O	0.04	0.02	0.2	0.14
K_2O	0.01	0.02	0.01	0.11
H_2O-110°.	0.03	0.02	0.03	0.67
H_2O+	1.67	0.97	1,41	
CuO	n.d.	n.d.	0.8	0.73
BeO	n.d.	n.d.	0.3	n.d.
F	n.d.	n.d.	1.5	1.72
—0 for F			0.6	0.72
Sum	100.24	100.26	99.5	100.03

of reaction between bedrock and slowly moving solutions or material transported by diffusion to the site of reaction. If the movement of the mineralizing medium is sufficiently slow as it reacts with the bedrock, it may easily acquire a different chemical composition in different parts of the deposit giving rise to variation in the reaction products. This interpretation would seem quite feasible if it were confirmed by other observations. That is not the case, however. The finegrained lumps of epidote described above are in all probability altered inclusions of bedrock. Transitional stages between the finegrained epidote lumps and the coarsegrained masses of quartz-thulite-cyprin-grossularite have never been found, nor are there in the deposit any palimpsest structures of the bedrock or any traces of «ghostly remnants».

In the case of a contact-metasomatic grossularite-vesuvianite-fluorite deposit the source of the chemical constituents is fairly obvious. In the present case the problems are much more complicated. The deposit is situated in a regionally metamorphosed and granitized area, and it can only in a general way be referred to the mobilization of ions during the process of regional metamorphism and granitization. A thorough study of the petrology of the rocks of the area may shed some light on the formation of the deposit under discussion. With the pressent knowledge of the petrogenesis of the local rocks and the present understanding of processes of mineral formation in general, a number of problems concerning the genesis of the Sauland deposits must be left unsolved.

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ON LOELLINGITE ($FeAs_2$)

BY

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Abstract. Four new localities for loellingite, one British and three Norwegian are given.

A chemical analysis of the loellingite from Drag, North Norway, is presented.

The powder patterns indicate minor differences in the lattitces of the loellingites from different localities. Based on patterns of naturally occurring minerals and a few syntheses, it seems possible to explain the pattern differences by a varying content of sulphur substituting for arsenic in the crystal structure. Similar differences are also noted in the arsenopyrite group.

Loellingite from the Bedford United Mine (?), Tavistock, Devon, England.

A number of mineral specimens from Gregory, Bottley & Co., purchased for teaching purposes, were checked at the University of Leeds. X-ray powder photographs were taken as a matter of routine, and it was discovered that a specimen labelled arsonopyrite from the Bedford United Mine, Tavistock, did not give an arsenopyrite pattern.

A rapid chemical analysis carried out in the Department of Geology, the University of Leeds, by LARS LUND, indicated that $FeAs_2$ was the probable chemical formula. Attention was then turned to loellingite. The powder diagram was compared with a diagram of an analysed sample of loellingite from Franklin, New Jersey, which was obtained through the kindness of Dr. C. FRONDEL. The sample was from specimen H.90822 in the Harvard Collection and the analysis is given by BAUER and BERMAN (1). Loellingites from various Norwegian localities in the collection of the Mineralogical Museum, Oslo, were also examined and they all gave the same powder pattern. The identification of the Tavistock mineral as a loellingite is therefore beyond doubt.

There is a slight uncertainty, however, as to the origin of the samples. Unfortunately none of the authors has had an opportunity to visit the Bedford United Mine to try to confirm the loellingite on the old dumps.

Loellingite from Rusnesvann, Hofsherad, Rogaland, South Norway.

Some specimens from the Hofsherad locality were sent by a prospector to the Mineralogical Museum, Oslo, for identification. In addition to pyrite the specimens contained two steel-gray minerals giving the characteristic X-ray powder patterns of arsenopyrite and loellingite. Loellingite must be rather scarce at Rusnesvann as one of us (K.H.) spent several hours in search of that mineral during a visit to the locality in July 1954, but without any success.

The occurrence is situated on the very steep hill about 300 m above the road on the east side of Rusnesvann in Hofsherad. Some quarrying has been done along rust zones running parallel to the foliation of the surrounding rocks, the direction of which varies to some extent around the average values N 15° W and 15° E.

Quarts veins occur in the rust zones, and the minerals mentioned are found in these veins.

The surrounding rocks are amphibolite and a peculiar white, garnet bearing quartzfeldspatic rock which may have a pegmatitic appearance. Similar rocks, also with rust zones, are known along the strike some miles further north-west, where it is tentatively interpreted as border migmatite between the charnockites in the Egersund-Sogndal region and the granitic gneisses of the Telemark region. The age relationship of these two rock suites is uncertain, but they probably both belong to the Precambrian.

At Hofsherad graphite is found along the foliation planes.

Loellingite from Lapplegret, Drag, Tysfjord, North Norway.

At Drag in Tysfjord a number of pegmatite dykes have been worked for feldspar and quartz. Quite big lumps or lenses of loellingite enclosed in pegmatite are found close to the entrance to the lower of the two quarries called Lapplegret. Quartz is quite abundant in the loellingite masses, and the only other minerals found in this paragenesis are arsenopyrite as scattered crystals and molybdenite in very small amounts.

An analysis of the loellingite from Drag is presented as No. 4 in table 2. An optical spectrogram showed the presence of about 0.1 percent Ni, and about 0.01 percent Bi, while no lines of Sb could be seen on the plate. The specific gravity is 7.18.

Loellingite from Seteråsberg, Modum, South Norway.

The Naturhistoriska Riksmuseet in Stockholm has two specimens of loellingite labelled Sätersberg, Modum, Norway (Nos. L.K. 6981 and L.K. 6982). Sätersberg is probably a misnomer for Seteråsberg. The loellingite occurs as small lenses (2.0 × 0.5 cm) in a matrix of quarts, feldspar and muscovite. The specimens are certainly not from any of the cobalt mines in Modum but originates from one of the pegmatite dykes so numerous in this district.

Experimental data and discussion.

A powder camera with 9 cm radius, Fe radiation and Mn filter was used for the X-ray investigations. The d-values of four analysed loellingites which will be used for the discussion are given in table 1. The values given by PEACOCK (5) for the Franklin loellingite (Fe radiation) are quoted as No. 2 in the table, and the indices and intensities which are used are those given by him. Through the courtesy of Dr. C. FRONDEL we received from the Harvard collections a sample of the original Franklin loellingite which was used for direct comparison. From G. PEHRMAN, Åbo Academy, we received a sample of an analysed loellingite from Kuortane (No. 3, table 1) earlier described by him (6).

During the work minor differences in the powder patterns for the loellingites from different localities were noted.[1] The differences can best be described as a splitting up or narrowing of pairs of lines, although there are also minor variations in the relative intensities of the lines. Fig. 1 shows the two most extreme pattern types encountered during these investigations.

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[1] It should be mentioned in this connection that the pattern given by HARCOURT (3) for loellingite is not the pattern of that mineral as already noted by PEHRMAN (6). HARCOURT's loellingite material is arsenopyrite.

Loellingite has a marcasite structure with the space group V-$^{12}_{h}$ as shown by Buerger (2) whose work is based on material from Franklin. Since most older analyses show Fe in excess of the $FeAs_2$ ratio, Buerger considers solid solution of iron in loellingite so common as to be the rule rather than the exception, and that the iron in excess of the ideal formula proxies for arsenic in the crystal structure. This would, as pointed out by Buerger, give the following specific formula for loellingite,

$Fe_{2+x}As_{4-x}$ (with x probably not exceeding 0.2).

In order to investigate if excess iron could explain the variations in the powder patterns of naturally occurring loellingites, a number of syntheses were carried out. Iron and arsenic were weighed in the required amounts, thoroughly mixed, placed in evacuated glass tubes and heated. The products were examined by X-ray photographs. No differences could, however, be seen between the patterns of the products with excess iron and the one with the ideal composition $FeAs_2$ (No. 1, table 1, heated 90 hrs. 560° C.). Probably most of the excess iron did not take part in the reaction.

Pehrman (6) points out that most modern analyses show good agreement with the formula $Fe(AsS)_2$, and suggests that the excess iron in the older analyses in most cases may be explained as analytical errors.

As the analyses published of loellingites show a varying amount of sulphur replacing arsenic in the crystal structure, attention was turned towards this element as being the possible cause of the differing powder patterns. According to Dana (4) the maximum content of sulphur in loellingites seems to be around 7 percent (6.73 percent S, McCay in Dana 1892). This value is, however, unique in being extremely high. More modern analyses only rarely exceed 2 percent S.

In table 1, Nos. 1—4 are arranged with increasing amount of sulphur. (For analyses, see table 2).

A comparison of the chemical analyses in table 2 with the d-values in table 1 gives at first a somewhat confusing impression. The d-values of Nos. 1—3 are pretty close to each other, while No. 4, Drag, differs considerably. Considering the extremely high sulphur

TABLE 1.

		d in Å			
Ind.	I	1	2	3	4
				3.82	
		2.94		2.95	
012	vs	2.59	2.59	2.59	2.57
110	s	2.52	2.52	2.53	2.53
021	m	2.41	2.41	2.41	2.38
111	vs	2.32	2.32	2.33	2.33
022	w	1.975	1.974	1.975	1.957
112	vw	1.920	1.921	1.925	1.929
013	m	1.855	1.857	1.855	1.845
121	m	1.840	1.846	1.845	1.845
031	s	1.686	1.689	1.686	1.672
		1.632		1.635	1.634
103	s	1.626	1.630	1.630	1.629
		1.609			
023	vw	1.586	1.589	1.586	1.573
113	vw	1.560	1.559	1561	1.560
130	w	1.500	1.498	1.500	1.496
004	w	1.490	1.498	1.490	1.484
		1.481			
014	m	1.436	1.436	1.438	1.459
200	m	1.436	1.436	1.438	1.459
123	w	1.388	1.390	1.391	
132	w	1.341	1.342	1.342	(1.336)
033	vw	1.317	1.320	1.315	(1.307)
024	w	1.297	1.300	1.296	(1.289)
202	vw	1.289	1.293	1.286	(1.274)
		1.275			
220		1.256	(1.260)	1.260	
212	m	1.256	1.257	1.260	(1.270)
221	w	1.235	1.237	1.237	(1.245)
				1.225	
042	vw	1.207	1.209		

Indices and intensities[2] after PEACOCK (5) 1. synthetic FeAs$_2$. 2. Franklin, New Jersey. *d*-values as given by PEACOCK. Figures in () represent calculated spacings. 3. Kourtane, Finland. 4. Drag, North Norway. Figures in () may not be placed under right indices.

TAbLE 1 (Cont.)

		d in *Å*			
Ind	I	1	2	3	4
141	vw	1.177	1.177	1.176	1.170
015	w	1.164	1.166	1.167	
213	w	1.138	1.139	1.142	1.146
142	w	1.114	1.115	1.113	1.107
105	w	1.103	1.104	1.103	
231	m	1.096	1.095	1.094	1.100
025	w	1.088	1.088	1.088	1.081
115	m	1.080	1.080	1.080	1.077
134	s	1.058	1.059	1.057	1.054

[2] We prefer to give the intensities in rather vague terms. The intensities seem to vary to a certain extent with the sulphur content and we do not wish to discuss that variation in the present paper.

TABLE 2.

	1		2		3		4	
	Weight percent	Cation percent	Weight percent	Cation percent	Weight percent	Cation percent	Weight percent	Cation percent
Fe	27.15	33.3	29.40	35.9	27.55	33.4	27.31	32.6
Co	—	—	—	—	—	—	1.29	1.5
Ni	—	—	—	—	—	—	tr	tr
Bi	—	—	—	—	—	—	tr	tr
Sb	—	—	—	—	—	—	none	none
As	72.85	66.6	69.80	63.6	70.63	63.8	67.60	60.1
S	—	—	0.21	0.5	1.34	2.8	2.77	5.8
	100	100	99.41	100	99.52	100	98.97[3]	100

1. $FeAs_2$ 2. $FeAs_{1\cdot77}S_{0\cdot01}$ 3. $FeAs_{1\cdot91}S_{0\cdot08}$ 4. $Fe_{0\cdot96}Co_{0\cdot04}As_{1\cdot76}S_{0\cdot17}$

1. synthetic $FeAs_2$. Heated 90 hrs. at 560° C.
2. loellingite, Franklin, New Jersey (anal. BAUER and BERMAN (1.) 1927).
3. loellingite, Kuortane, Finland (anal. P. KIVALO (6). 1950).
4. loellingite, Lapplegret, Drag, Tysfjord, North Norway (anal. E. CHRISTENSEN 1953).

[3] SiO_2 determined spectrographically to about one percent.

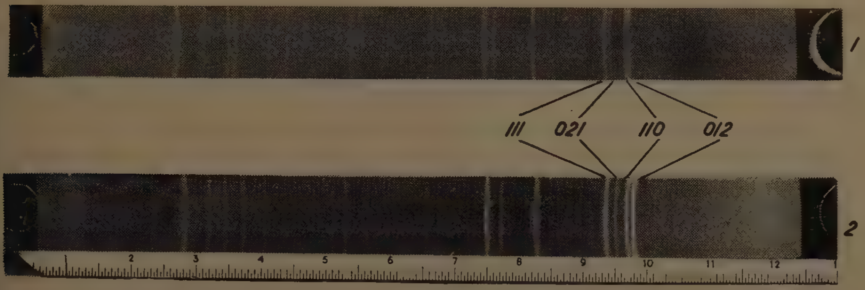

Fig 1. X-ray powder patterns of loellingites, 1. Drag, Tysfjord, North Norway. 2. Franklin, New Jersey.

content of this loellingite in comparison with the other three, this is of notable interest.

As shown in table 2 the Franklin loellingite has the most excess iron. BUERGER considers the slight deviation from the ideal formula as unimportant from a structural point of view and chose Franklin material for his investigations of the loellingite structure. Also, there is no correlation between the iron content and the variation of the patterns, and excess iron can, therefore, hardly explain the differences in the d-values observed. (This is in agreement with the syntheses). On the basis of the somewhat scanty data available at the

TABLE 3.

1	2	3	4
$d_{012}-d_{110} = 0.07$ Å $d_{021}-d_{111} = 0.09$ Å	$d_{012}-d_{110} = 0.07$ Å $d_{021}-d_{111} = 0.09$ Å	$d_{012}-d_{110} = 0.06$ Å $d_{021}-d_{111} = 0.08$ Å	$d_{012}-d_{110} = 0.04$ Å $d_{021}-d_{111} = 0.05$ Å
5	6	7	8
$d_{012}-d_{110} = 0.05$ Å $d_{021}-d_{111} = 0.07$ Å	$d_{012}-d_{110} = 0.045$ Å $d_{021}-d_{111} = 0.07$ Å	$d_{012}-d_{110} = 0.06$ Å $d_{021}-d_{111} = 0.07$ Å	$d_{012}-d_{110} = 0.05$ Å $d_{021}-d_{111} = 0.06$ Å

Nos. 1-4 correspond to numbers of table 1.
No. 5 Bedford United Mine, Great Britain.
No. 6 Hofsherad. South Norway.
No. 7 Seteråsberg, Modum, South Norway.
No. 8 Synhetic loellingite with sulphur.

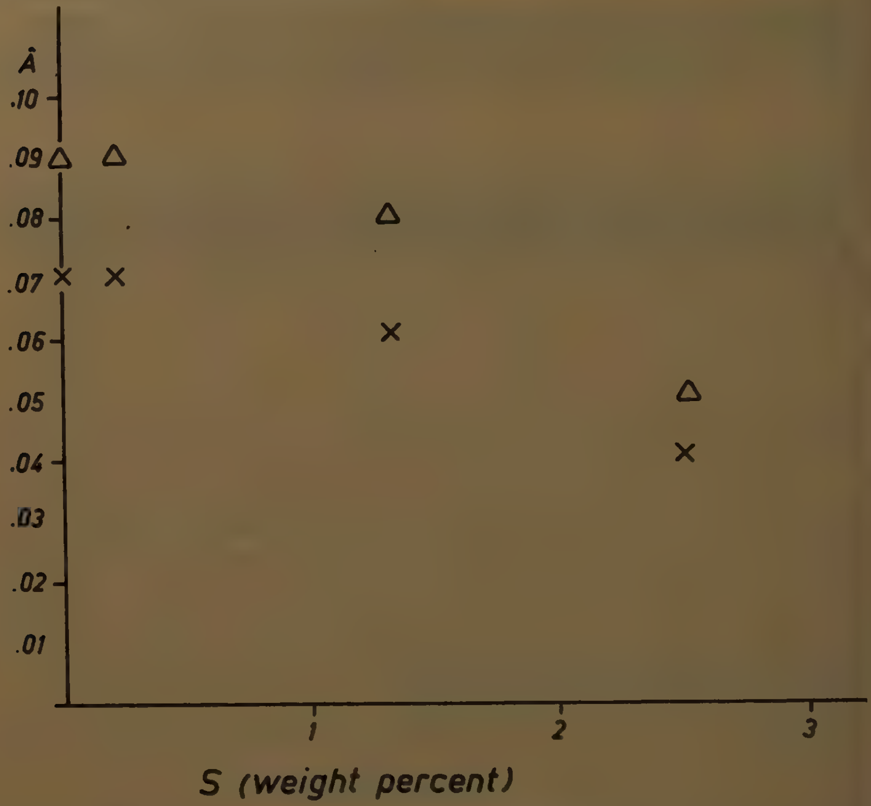

Fig. 2. Differences in Å between the spacings of the planes d_{012}—d_{110} (crosses) and d_{021}—d_{111} (open triangles) in relation to sulphur content of analyzed loellingites, (see tables 2 and 3).

present time, it seems, on the other hand, perfectly feasible to explain the differing d-values as a result of the variations in the sulphur content. It is even indicated that the narrowing of the pairs of lines 012—110 and 021—111 (see fig. 1) may be used as a direct measure of the sulphur content of loellingite. Differences in Å between the spacings of the planes concerned are given in table 3 for the different samples investigated by us.

From the table a narrowing of the two pairs of lines as we pass from Nos. 1—4 is evident. The Franklin loellingite (No.2) with a low sulphur content is very similar to the synthetical $FeAs_2$ (No. 1), in agreement with the statements above. The sulphur rich variety from Drag shows the largest deviations from synthetical $FeAs_2$ (see Fig. 2). The Bedford United Mine, Hofsherad and Modum specimens seem to belong somewhere between the Franklin and Drag specimens.

In order to check if sulphur really does give deviations as indicated in the crystal structure, a further synthesis was carried out. Fe, As, and S in amounts corresponding to 90 mol percent $FeAs_2$ and 10 mol percent FeS_2 were placed in an evacuated glass tube and heated at 600° C for 90 hrs. After this time free sulphur was still to be seen in the tube, and the loellingite produced by the experiment is thus presumably saturated with respect to sulphur under the prevailing P-T-conditions. The d_{010}—d_{111} and d_{021}—d_{111} values are listed as No.8 in table 3. From the table it is evident that the higher sulphur content of this synthesis, as compared with the pure synthetic $FeAs_2$, is confirmed by the narrowing of the critical lines.

It is shown above that it is possible to explain the differences observed in the loellingite powder patterns by a varying amount of sulphur substituting for arsenic in the crystal structure. Other explanations can not be excluded, however, until more data is available.

Differences are noted in the powder patterns of arsenopyrite, similar to those described for loellingite, and the authors believe that the variations in these closely related structures have the same causes. To settle these problems further investigations in the system Fe-As-S are needed.

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KJEMISK BERGARTSFORVITRING BELYST VED EN DEL LEIRPROFILER

AV

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Abstract. The adsorbed cations through some clay profiles in eastern Norway have proved that a weathering of the potassium bearing minerals has taken place *in situ* in post-glacial time. This weathering is specially high in the upper 5—6 metres.

It is infered that the solid rocks may undergo similar weathering although the water content and porosity are much lower.

Innledning.

Problemet om kjemisk bergartsforvitring etter istiden under de klimatiske forhold som har hersket i Skandinavia, har vært en del diskutert i den geologiske litteratur i de senere år. I Norge har LÅG (1), DAHL (2) og STRAND (3), i en del arbeider behandlet disse forhold forholdsvis inngående. Det synes å herske enighet om at visse bergartstyper forvitrer lettere enn andre, og at det på sine steder finnes dyptgående forvitring i fast fjell, selv på steder der innlandsisen under istiden må antas å ha fjernet alt pre- og inter-glasialt forvitringsmateriale. Tilsynelatende tette homogene bergarter viser seg ved nærmere undersøkelse å være gjennomsatt av et meget fint nettverk av forvitringsmateriale, slik at bergarten kan tas ut med hakke og skyffel og direkte anvendes som veggrus.

BARTH (4) har beskrevet forekomsten av slik grusartet stein på Sørlandet og hevder at denne forvitring mellom mineralkornene er av inter-glasial opprinnelse. I det tilfelle Barth beskriver, har han funnet et innhold av leirmineraler mellom kornene. Barth har beregnet disse som «beidellit». Senere undersøkelse (5) har vist at det dreier seg om en blanding av bauxitmineraler og montmorillonit.

På Runde utenfor Ålesund har Dahl (6) vist at tilsvarende oppsprukket og forvitret fjell inneholder montmorillonitmineraler. I dette tilfelle antar Dahl at forvitringen er av pre-glasial eller interglasial alder og slutter derav at landisen ikke dekket Runde under siste istid.

Imidlertid finnes på Runde uforvitrede flyttblokker oppå forvitret fjell, slik at det ikke kan herske tvil om at landisen iallfall dekket store deler av Runde under siste istid, selv om forvitringen som har dannet leirmineralene i gneisen under kan ha vært interglasial eller pre-glasial.

Da man tidligere har antatt at dyptgående forvitring ikke kan finne sted i løpet av den forholdsvis korte tid som har passert siden istiden under klimatiske forhold som de man har i Skandinavia, er det verdt å peke på at allerede Olof Tamm (7) viste at feltspatt kunne angripes meget kraftig av iskoldt vann.

Erik Norin (8) har vist at hydroglimmermineraler er oppstått i forholdsvis unge sedimenter på bunnen av det Thyrenske hav i Middelhavet.

Nyere undersøkelser.

Ved studier av norske leirer har en ved Norges geotekniske institutt kommet frem til en del forhold som klart viser at det finner sted en forvitring *in situ* i våre leirsedimenter. Som et eksempel kan nevnes at vi har bestemt hvilke joner som er adsorbert i leirmineraler i et leirprofil på Bryn i Oslo. I dette leirprofilet var kornfordelingskurven meget ensartet fra toppen og nedover.

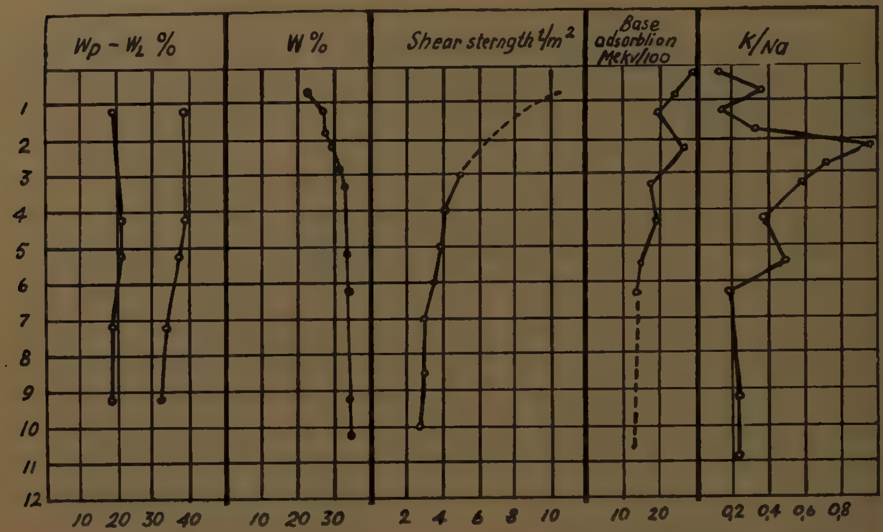
Ved differensialtermisk undersøkelse fant vi likeledes at den mineralogiske sammensetning var forholdsvis ensartet, idet finfraksjonen, d.v.s. partikler finere enn 2 mikron, inneholdt en meget konstant prosentdel hydroglimmermineraler: ca. 60 %. For å bestemme hvilke katjoner som var adsorbert til leirmineralene ble det foretatt jonebytningsforsøk. For dette formål anvendtes den kunstige jonebytterharpiks Dovex 50. Analysen ble foretatt på den måte at en leirmengde som svarte til ca. 300 gram tørrmateriale, ble dispergert i destillert vann, slik at alle løselige salter ble vasket ut. Deretter ble leiroppslemningen sentrifugert, og bunnfallet ble blandet med jonebytterharpiksen i dens hydrogentilstand. Det anvendtes en harpiksmengde som svarte til ca. halvparten av leirvekten. På grunn av harpiksens meget høye jonebytningsevne fikk vi en nesten fullstendig utbytning av protonene fra harpiksen og metallkatjonene som var adsorbert på leirmineralene. I tillegg til dette kom så at harpiksen reagerte meden del mineraler som var lett løselige f.eks. gips, kalsiumkarbonat, magnesiumkarbonat, jernhydroksyder osv.

Gipsen ble for eksempel overført til svovelsyre samtidig med at harpiksen gikk over til kalsiumtilstand i ekvivalente mengder. På tilsvarende måte ble kalsiumkarbonatene angrepet under dannelse av kullsyre. Vi måtte derfor finne en korreksjon for disse mineralkomponenter, idet de katjoner vi senere kunne bestemme på harpiksen ikke utelukkende stammet fra joner som hadde vært adsorbert på leirmineralene. Når det gjelder alkalimetallene må man imidlertid gå ut fra at all natrium og kalium som fantes på jonebytterharpiksen stammet fra leirmineralene ved en jonebytningsreaksjon.

Forholdet kalium til natrium kunne bestemmes ved at jonebytterharpiksen ble silt fra leirfraksjonen og deretter vasket med fortynnet saltsyre. I filtratet ble så kalium og natrium bestemt flammespektrometrisk. På figur nr. 1 ser en hvorledes kali-natron-forholdet er konstant ca. 0.2 i de dypereliggende deler av profilet, mens det stiger raskt fra 6 meters dyp og opp til 1½ meter under overflaten. Her er kali-natron-forholdet ved et maksimum på ca. 0.95. I den øverste del av profilet avtar forholdet igjen raskt, slik at man kommer ned i 0.12 like under gressrøttene. Det synes som om vegetasjonen har ekstrahert kalium fra jordens øverste lag.

Ser en på jordens baseadsorbsjonsevne, finner en at denne er forholdsvis lav i de dypere deler av profilet, men stiger raskt mot overflaten. Da hverken den høye baseadsorbsjonsevne eller det høye kali-natron forholdet kan forklares ved en primær variasjon i mineralinnholdet, kommer en til at det iallfall av et dyp av 6 m har foregått sekundære prosesser i leiren som har skaffet frem kalijoner i slik mengde at de har kunnet fortrenge en del av det primære adsorberte natrium og derved gitt et økt kali-natron-forhold, blant de adsorberte katjoner.

Ved undersøkelse av porevannet i Bekkelagsleiren fant en et til-



Sammenstilling av plastisitetsgrense, flytegrense, naturlig vanninnhold, baseadsorbsjonsevne samt forholdet mellom adsorbert K^+og Na^+i et leirprofil ved Bryn, Oslo. (Dybde i meter).

svarende fenomen. Her ble ikke de øverste 2 m undersøkt, men dypere viste kali-natron-forholdet følgende variasjon:

K/Na
2.5 m — 0.71
4.0 m — 0.64
5.0 m — 0.40
6.0 m — 0.47
7.0 m — 0.36
8.0 m — 0.33
10.1 m — 0.33

I disse leirer inneholder vannfasen *mer* kalium enn sjøvannet. gjør.

Også i dette tilfelle dreier det seg om en meget homogen leiravsetning (isocardialeire). Kornfordelingen var inntil analysenøyaktigheten identisk, og mineralinnholdet det samme, hovedsaklig en hydroglimmerleire. Senere har andre analyser foretatt på mineraler fra Ullevål vist liknende forhold.

Konklusjon.

Ved bestemmelse av jordartenes mekaniske egenskaper har det vist seg å være en generell regel at skjærfastheten i uforstyrret tilstand øker rettlinjet nedover mot dypet i homogen leiravsetning. Dette gjelder imidlertid bare under et visst dyp, i alminnelighet 5—6 m, og kun for normal belastede leiravsetninger, som ikke tidligere har båret vekten av større jordmasser enn den nåværende overlagring.

I høyere nivåer øker leirenes skjærfasthet betraktelig, selv om vanninnholdet er konstant. Dette er blant annet belyst av BJERRUM (9) (10). Like ledes øker leirers flytegrense [1]betraktelig i de øvre nivåer. Denne observasjon er så alminnelig at man kan bruke det som en fast regel, og dersom man ikke finner dette forhold, viser det seg som oftest at leirprofilet ikke har vært homogent.

Undersøkelser av leirjordartens mekaniske egenskaper som funksjon av elektrolyttinnholdet har vist at ved et bestemt vanninnhold (11) har kalileirer høyere flytegrense enn natronleirer, og skjærfastheten for kalileirer i omrørt tilstand er alltid meget nær det dobbelte av skjærfastheten for natronleirer i omrørt tilstand. Det er altså åpenbart at alle våre østnorske leirer ned til et dyp av 5—6 m har et høyere kali-natron-forhold enn de dypereliggende nivåer. Slik sekundær forskyvning av forholdet mellom de adsorberte joner kan kun forklares ved at det har foregått en forvitring *in situ*, iallfall ned til et dyp av 5—6 m.

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[1] Det vanninnhold hvor prøvens konsistens skifter fra å være usammenhengende og smuldrende til å være plastisk, kalles *utrullingsgrense* (*wp*), definert som det vanninnhold som gir prøven en slik konsistens at den kan rulles ut til 2—3 mm tynne tråder, men hvor en uttørking vil føre til at materialet smuldres ved utrulling.

Flytegrensen (*WL*), som angir det vanninnhold hvor konsistensen skifter fra plastisk til flytende, er definert ved et standardisert forsøk med Casagrandes flytegrenseapparat, idet den bestemmes som det vanninnhold som får en liten fure i prøven, av gitt form til å lukke seg over en lengde av 12 mm for 25 slag.

Det vanninnholdsintervall innenfor hvilket en leirprøve er plastisk, kalles *plastisitetsindeks* (*Ip*). Det defineres som differensen mellom flytegrensen og utrullingsgrensen.

Man regner vanligvis en leires aktivitet som forholdet mellom plastisitetsindeks og prosentinnhold av mineraler finere enn 2μ.

Imidlertid viser også de relativt høye kali-natron-forhold i dypereliggende deler av leirprofilene at det har foregått en viss forvitring også under 5—6 m dyp. I disse dypereliggende deler har imidlertid forvitringen vært vesentlig mindre enn de øvre deler, og forvitringen har hatt samme størrelse i alle dyp. Nå er nettopp 5—6 m det dyp hvortil sommertemperaturens innflytelse gjør seg gjeldende i våre leiravsetninger. Undet dette dyp er temperaturen konstant året rundt og lik stedets middeltemperatur. Vi kommer følgelig til den konklusjon at en kort tid med temperatur over årets middeltemperatur mer enn oppveier det forhold at leiravsetningen også en tid har vært under årets middeltemperatur.

Videre kommer man til at det stadig i den tid som har gått siden istiden har forekommet en kjemisk forvitring av mineralene i våre leiravsetninger. Dette har ført til frigjøring av kalijoner, hvorfor man må slutte at i særlig grad kalimineraler har deltatt i forvitringsprosessen. Ellers har forvitringen ført til økning av leirmineralenes «aktivitet», noe som kjennetegnes ved den økte baseadsorbsjonsevne for mineralene fra Bryn.

Da det prinsipielt ikke er noen forskjell på de mineraler vi har i våre kvartære leirer og de mineraler vi har våre bergarter, må en trekke den konklusjon at det også i våre faste bergarter må foregå en kjemisk forvitring, iallfall ned i et dyp av 5—6 m, men at denne forvitring i de faste bergarter i alminnelighet gir seg mindre tydelige utslag, sannsynligvis på grunn av lavt vanninnhold eller på grunn av den lave porøsitet.

I visse tilfelle har en imidlertid bergarter der fuktigheten kan sipre ned langs hårfine sprekker mellom mineralkornene. I slike bergarter bør en derfor forvente en like høy grad av kjemisk forvitring som det man har i våre leirer, muligens enda høyere, idet våre leiravsetninger primært inneholder store mengder oppløste metalljoner og derfor har mindre hydrolyserende virkning enn det rene regnvann som trenger ned i mikrosprekkene i våre faste bergarter. Vi antar at nettopp denne form for forvitring er virksom i alle bergarter, men at det kun er i ekstreme tilfeller at bergartene har en så høy grad av mikrosprekker at man får de utpregete grusartede dannelser som for eksempel Barth og Dahl har beskrevet.

Hermed skal intet være sagt om disse forvitringers alder, idet sprukkent fjell meget vel kan tenkes oppbevart fra siste inter-glasial tid på steder der isskuringene har vært liten. Vi vil kun peke på at det ikke er nødvendig å anta noen pre-glasial prosess for å forklare dyptgående forvitring. I de tilfeller Låg og Strand har beskrevet kan det således ikke herske tvil om at forvitringen har vært post-glasial.

SUMMARY

The problems in connection with chemical weathering of rocks in Scandinavia in the time after the ice age are very important. Several occurrences of clay minerals have been interpreted as inter-glacial formations, as it is believed that the cold climate and the short time since the ice age were insufficient to produce any chemical weathering worth mentioning. By investigations in clay profiles is, however, found that marked chemical weathering takes place especially down to a depth where the summer temperature is active. This weathering is important. Due to the weathering, potassium ions are liberated from the minerals' lattices. These potassium ions in turn take part in exchange reactions, and sodium and magnesium ions adsorbed on the marine clay minerals during deposition are removed. Simultaneously the «activity» of the clay minerals increases, as shown by the base exchange capacity. It is concluded that there is no principal difference between minerals in Scandinavian normal clays and the minerals in the solid rocks. Therefore similar weathering processes may take place in any rock where sufficient porocity allows the water to pass through fine cracks and fissures.

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Manuskript mottatt 6. oktober 1954.

LITT KVARTÆRGEOLOGI FRA JERNBANEDALEN MELLOM ORKDAL OG OPPDAL

AV

BJØRGE LØKÅS

Abstract. On the watershed between Orkdal and Oppdal in the environments of Fagerhaug railway station, are to be seen a number of quaternary ice deposits, especially marginal terraces.

Measurements carried out by the author show taht the higher terraces have a greater gradient eastwards than the .ower ones. The lowest level shows a horizontal direction of 8 km. This level corresponds in altitude to the watershed between Orkdal and Oppdal. This implies, that at the time when the watershed was freed from its ice-sheet, the surface of the ice had evened out so as to be practically horizontal. The rising of the ground is not likely to have exerted any decisive influence on the gradient of the terraces. In this grand dead-ice region an «esker», covering some 3 km, is of particular interest. Its size and shape make it one of the most inpressive of its kind in this country. When taken in conjunction with *Arne Grønli's* observations from the Orkelsea regions, the direction of these terraces proves that in the case of Orkdal the last remnants of the inland ice were to be found in the middle of the valley.

I sitt omfattende arbeid «Kvartærstudier i Trondheimsfeltet», III, Kgl. N. Vidsk.selsk. Skr. 1914, nr. 6, gir P. A. ØYEN bl.a. noen glimt av de kvartærgeologiske forhold inne i Bynasdal på overgangen mellom Orkdal og Oppdal, fig. 1 og 2. Han sier bl. a. på s. 117: — «Naar vi saa river os løs fra disse interessante omgivelser af moskusoksefindestedet i Indset, saa finder vi om skydsstationen Stuen flere steder et interessant morænelandskap, i dette saaes ogsaa paa sine steder vekslende lag af grus og sand. Gjennem tildels liknende landskap passeres derpaa Bjørnsvand med omkringliggende tjern og myrstrækninger og snart efter vandskillet med et tjern paa hver side og skogklædte omgivelser.» Videre siteres i samme forbindelse fra side

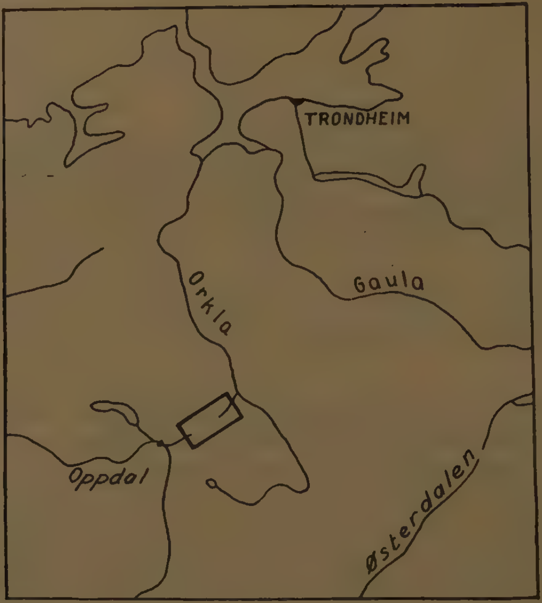

Fig. 1. Oversiktskart. Innfelt det undersøkte området mellom Orkdal og Oppdal.

118: — «Længere mot sydvest, mot Aune, har man vakkert «paysages morainiques» med hauger, kjedler og tvers over dalen gaaende mere eller mindre bueformede rygge, idethele et kupperet morænelandskap strøet med tildels svære blokke og svarende til det kupperede morænelandskap paa nordøstsiden av vandskillet, medens strækningen mellem disse to moræneafsnit utgjøres af en utstrakt, vid og grund dalbund, der i meget bærer præget af at ha utgjort en gammel sjøbund.»

I tilknytning til kvartærgeologiske undersøkelser som jeg i de senere år har foretatt innenfor selve Orkladalføret, arbeidet jeg somrene 1953—54 også endel i traktene rundt vannskillet mellom Orkdal og Oppdal i det terreng som Øyen omtaler, for også fra denne kant å få et innblikk i forholdene under isavsmeltingen.

Det er særlig området mellom Fagerhaug st. og vannskillet som har vært gjenstand for undersøkelsene. Her er den sydlige dalside sterkt skogvokst, med bare noen få åpne plasser. Grunnen til at det her nesten ikke fins gårdsbruk, er ikke bare at dalsiden er nordvent, men først og fremst det store antall av moreneblokker som tildels over kilometerlange strekninger utgjør et nesten sammenhengende dekke i dalsiden. Blokkmateriale fins riktignok også på nordsiden av Byna, men på langt nær ikke i slike mengder.

En vil i søndre dalside først og fremst mellom Langvella og Tinnia finne en rekke mektige terrassetrinn — men bare et par av disse er synlige fra dalbunnen. Hadde dalsiden vært skogløs, ville denne fremstått som et storslått terrasselandskap. Men skogen har en egen evne til å viske ut terrengdetaljene slik at selv terrasseflater med bredder på 100—200 m ikke kan sees fra motstående dalside. De mest markante trinn er beskrevet nedenfor. De tar til i området mellom Bjørnsvann og Nordre Gråhø og er gått opp herfra og mot nordøst mot Langvella.

1. Den høyestliggende terrasse finner vi i 787 m høyde nordvest for Nordre Gråhø. Den kiler ut i storstenet ur etter ca. 600 m. Høyden var her 798 m som gir en stigningsgradient på 1,9/100. Terrasseflaten er tildels vel planert, 15—20 m bred og utgjøres for det meste av storstenet materiale iblandet grove blokker.

2. 82 m lavere treffes neste terrasse som etter en strekning på 400 m viste samme stigningsforhold som foregående. Terrasseflaten, ca. 30 m bred, består tildels av grovt blokkmateriale. Der var også en flere meter bred dreneringsrenne i innerkant.

3. I 665 m h. o. h. er der en terrasseflate av omtrent samme bredde som foregående. Den er også blokkrik men noe mer ujevn. Etter 400 m var høyden 671 m, som gir en gradient på 1,5/100.

4. Like nedenfor Ranumseter tar det til en terrasse i høyden 624 m o. h. Etter ca. 550 m mot nordøst løser flaten seg opp i storstenet ur. Høyden var her 628 m, som gir gradienten 0,7/100. Terrasseflaten som var opptil 80 m bred, fører til dels fint grus og har i den sydvestlige del en bred dreneringsrenne i innerkant.

5. Det neste markante trinn tar til rett syd for Bjørnsvann i 619 m høyde, og følges frem til Langvella. Distansen er ca. 3 km. Da terrasseflaten viser en del uregelmessige forhold nærmest Langvella, er gradienten regnet ut etter de første 2,5 km, og er som i foregående tilfelle 0,7/100. Terrasseflaten er stort sett vel planert og består hovedsaklig av storstenet materiale. Bredden er enkelte steder opptil 200 m. Også her er det en dreneringsrenne i terrassens sydvest-

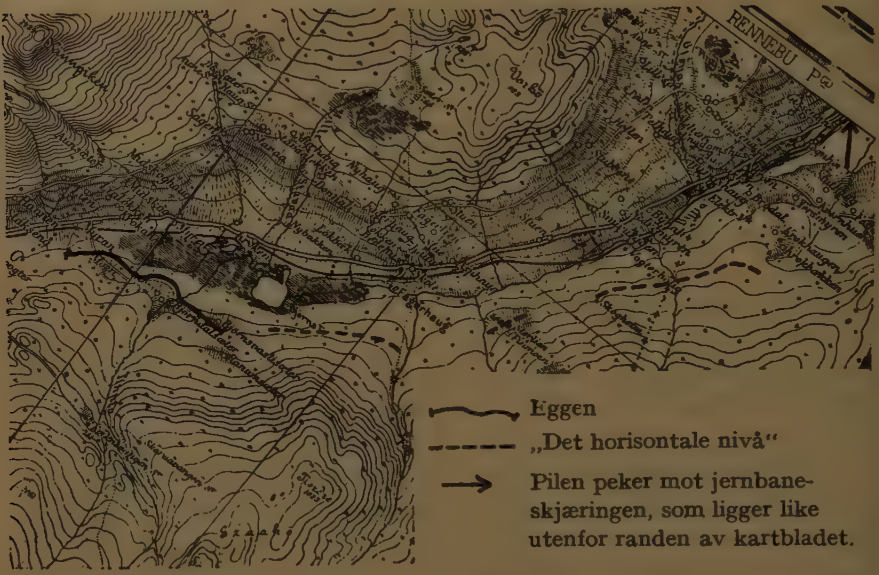
RENNEBU Pg
Eggen
„Det horisontale nivå"
Pilen peker mot jernbaneskjæringen, som ligger like utenfor randen av kartbladet.

Fig. 2. Den østlige del av «jernbanedalen» mellom Orkdal og Oppdal. Utsnitt av rektangelkartene Oppdal og Kvikne.

lige del som viser at store vannmasser har funnet avløp langs terrassens innerkant.

6. Den gjennomgående bredeste terrasseflaten påtreffes litt øst for Bjørnsvann og følges også frem til Langvella. Høyden var ved begynnelsen 564 m o. h., og etter ca. 2,5 km var den steget til 567 m o. h. Dette gir en gradient på 0,1/100. Flaten har i den sydvestre del flere store grytehull som viser terrassens umiddelbare kontakt med en isbre. Det er en god del finere materiale i denne terrassen — men blokker påtreffes fremdeles.

Det er nå verdt å legge merke til at dette siste nivå i høyde korresponderer med terrassen «Finnmoen» som er angitt på rektangelkartet med høyden 569 m. o. h Dette høydemålet har jeg ikke kontrollert. Derimot har jeg målt det markante terrassetrinn som tar til lengre nord ved Skogheim i 570 m høyde, og som er meget iøyenfallende fra nordre dalside. Fra Skogheim tiltar bredden av terrasseflaten, slik at den etter 2 km like øst for sagbruket ved Bynali (Gisna st.) har en bredde på ca. 350 m. Herfra følges terrassen videre ca.

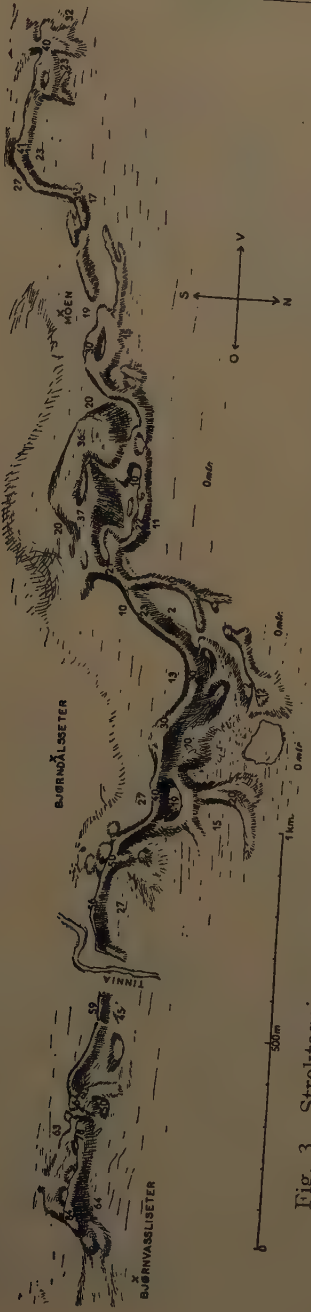

Fig. 3. Strektegning av eggen på vannskillet mellom Orkdal og Oppdal. (Tegnet av Joh. Stene).

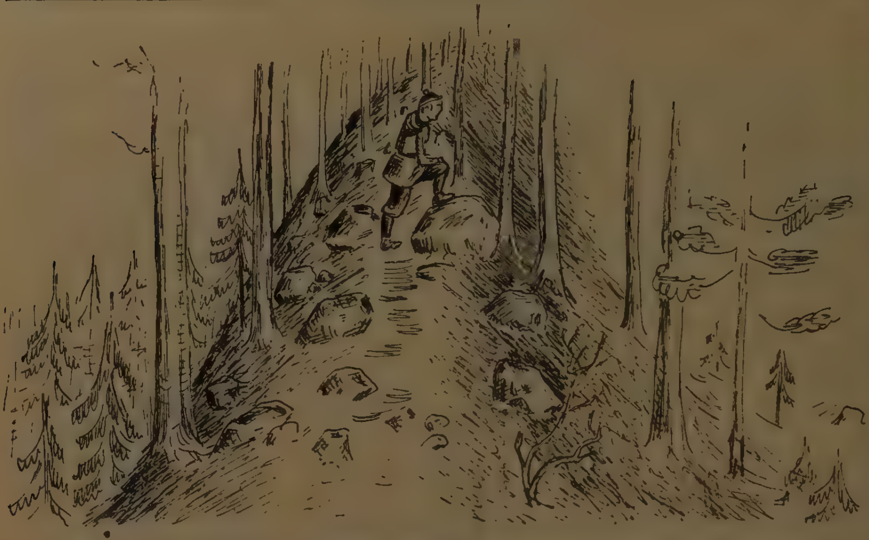

Fig.4. Detaljbilde fra eggens østlige del. (Tegnet av Joh. Stene).

1 km, nå mer mot øst. Den smalner hurtig av igjen, og løser seg etter hvert opp i uregelmessige hauger, og terrenget senker seg raskt mot samløpet av Byna (Gisna) og Orkla. Terrasseflatens høyde var hele tiden omtrent den samme som ved Skogheim. Noen stigningsgradient kunne ikke påvises. Snitt i terrassen viser at ihvertfall den nordlige del delvis er oppbygd av lagdelt grus og sand.

Det «horisontale nivå» som her er rekonstruert i 7—8 km lengde i Bynas sydlige dalside, (fig. 2), korresponderer omtrent med passhøyden mot Oppdal, som er 563 m o. h.

Fig. 3 og 4 refererer seg begge til en egg, en «geitrygg», som stort sett er beliggende mellom Bjørnvassliseter i øst og Moen gård i vest. Eggen er i utforming en av de mest praktfulle i sitt slag her til lands, men siden den går gjennom sterkt skogbevokst terreng er den meget vanskelig å bli klar over før en er helt inne på den. Den tar til like nedenfor terrasse 4. Noen direkte sammenheng mellom eggen og terrassen kan ikke påvises. Utgangspunktet for de høydemål som er angitt på kartet fig. 3 har vært det horisontale myrområdet (dalbunnen) nord for eggens midtparti hvor formasjonen som helhet ligger lavest. Fra dette midtparti mot Bjørnvassliseter går eggen på skrå oppover dalsiden, og når like nedenfor terrasse 3 sin største høyde, 84 m over myra (626 m o. h.). Fra midtpartiet og vestover stiger terrenget en del mot vannskillet mot Oppdal. Eggen følger ikke den bredeste del av dalbunnen, men trekker litt opp i søndre dalside. Bredden av bunnen i eggen er vanligvis mellom 30 og 40 m, og høyden 15—20 m over terrenget. Sin største høyde, 29 m over terrenget, har eggen like vest for området hvor Tinnia har skåret seg gjennom den. Det fremgår ellers av kartet fig. 3 at det i dannelsestiden er blitt innesluttet isrester som har gitt opphavet til diverse grytehull.

I den østre halvpart fører eggen særlig grovt materiale, opptil mannshøye blokker, mens en i den vestre halvdel sjelden treffer på stener som er større enn en halv meter i tverrmål. En veiskjæring i eggen på østre bredd av Tinnia viser et fullstendig usortert materiale i eggens kjerne, mens det på nordsiden på eggens overflate er en tydelig lagdeling og sortering parallell eggens overflate til ca. 1 m dybde. Der hvor gårdsveien mellom Moen gård og hovedveien skjærer eggen er det et liknende forhold, men her fins spor etter sortering også i eggens midtparti. Materialene, selv de største blokkene, bærer preg av å være atskillig vannslitte.

Det fins — som ØYEN nevner — på begge sider av vannskillet tallrike morenehauger. De har en meget variert oppbygning. Ikke sjelden påtreffes hauger side om side hvor én kan bestå av de fineste kvabblag, mens den neste inneholder grovt, usortert materiale, og en tredje forener begge deler. Men de fleste må karakteriseres som vanlige avsetningsmorener.

Diskusjon.

Blokkmorenene.

De prøvene jeg har tatt av blokkmaterialet i søndre dalside, består av samme bergarter som i denne, og som i det tilgrensende fjellparti i syd. Blokkenes størrelse sammen med at de tildels er lite slitt forteller at de ikke kan være transportert langt. Det er derfor nærliggende å tro at de kan være revet ut fra selve dalsiden. Etter O. HOLTEDAHL og B. G. ANDERSEN (1953) har isbevegelsen en tid i disse trakter vært mot NNØ, d.v.s. noe på tvers av Bynas dal. Etter dette er det mer sannsynlig at storparten av blokkene må være kommet fra området like syd for dalføret, og hovedsaklig avlesset i dalens le-side, da det jo er påfallende lite blokkmateriale på nordsiden av Byna. Like syd for nordre Gråhø fins et slikt uttak hvorfra en bred stripe av blokker går nordover og oppover toppen av Gråhø. Blokkstripen ligger i dag som en størknet strøm.

Terrassene.

Terrassene kan på grunn av sin høyde over dalbunnen ikke forklares på annen måte enn at de er israndsdannelser, og at de representerer markante trinn i en avsmelting ovenfra og ned. Det laveste terrassetrinn (som her er tatt med) inneholdt også flere store grytehull som viser hvordan deler av dalbreen ble avsnørt og innesluttet av løsmaterialene.

Det ville være for lettvint å si at den stigningsgradient som er påvist for terrassene utelukkende skyldes isoverflatens stigning mot nordøst (nedover Bynas dal). Nærmest Langvella ville det naturlig nok ha hopet seg opp særlig mye av lømaterialer som kan gi terrassene en større gradient enn isoverflaten virkelig hadde. Dette er det tatt hensyn til. Videre vil landhevningen kunne hatt en viss innflytelse på terrassenes gradient, om da ikke terrassene løper parallellt med likehevningslinjene.

I. Undås (1942) har tegnet et isobaskart for kyststrøkene i Møre og Trøndelag. Etter dette kartet er det nå sannsynlig at isobasene for det innlandsstrøk det her gjelder går parallell med linjene ute ved kysten. Men det vil igjen si at Bynadalen har tilnærmet samme retning som isobasene, og vi kan ikke da vente at landhevningen skal ha influert i noen større grad. På de høyeste terrassene kunne den i alle tilfelle ikke ha hatt avgjørende innflytelse. Det må være den sterkere avtining mot vest mot kyststrøkene som er årsak til den stigningsgradient breen fikk nedover Bynadalen.

Det er eiendommelig å se hvor vel planert mange av disse store terrasseflatene er, enda de ofte består av grovt blokkmateriale. Men det er lite trolig at terrassene kan bli å betrakte som rene sidemorener fremført langs kanten av en bre i bevegelse, selvom breen en tid hadde en gradient bortimot 2/100. Innlandsisen var jo forlengst å betrakte som en klimatologisk dødis, og den eventuelle bevegelse her i Bynas dal måtte nå ha foregått mot vannskillet. Vi har hørt at de lavere terrasser — enda de er så godt som horisontale — fører samme grove materiale som de høyereliggende. Når vi nå dessuten vet at selve dalsiden er oversådd med moreneblokker, er det rimelig å anta at de store blokkterrassene hovedsaklig er utformet som følge av frysning og tining i området opptil breen. Det må være teleløsning som har skapt særlig ustabile forhold i dalsiden, og som etter hvert har ført blokkene ned i nivå med isen. Men her mellom isen og dalsiden vet vi at det lett dannet seg vannfylte områder, og det er da særlig svingninger om nullpunktet i dette randområdet som er årsak til det imponerende «mosaikkarbeidet» som terrasseflatene tildels er.

Eggen.

Både terrassenes dreneringsrenner og den omtalte egg viser at det en tid under avsmeltingen foregikk en kraftig drenering mot vest fra området øst for vannskillet. Man antar at slike egger kan være blitt til på to måter. Enten representerer de en gjenfylt dreneringskanal under isoverflaten, — eller de er grusfyllinger i issprekker hvor smeltevannet har skåret seg ned. I det første tilfelle viser eggen lagdeling i kjernen med mer eller mindre usortert materiale ytterst. I andre tilfelle hvor materialene skal ha rauset ned i en sprekk, må vi vente en dårligere sortering. Eggen mellom Bjørnvassliseter og Moen har en tildels fullstendig usortert oppbygning, og må derfor henføres til en slik sprekkdannelse. Men dette synes å medføre at dannelsen av eggen må ha foregått hurtig, ellers var det rimelig å se flere spor etter rinnende vanns arbeid.

Materialet er som nevnt betydelig vannslipt, og synes å stamme fra en gammel elveseng. Denne må i tilfelle i sin tid ha ligget oppå isoverflaten. Hvor dypt en slik iselv kunne grave seg ned i ismassene, ville jo være bestemt av høyden på vannflaten i eventuelle foranliggende isdemte «sjøer». En senkning av vannflaten her ville føre til at elveleiet ville bli fordypet, Det er ikke usannsynlig at det er en slik senkning, en uttapningskatastrofe, som har foregått i Oppdalstraktene, og som i neste omgang forårsaket at vannmasser som ble drenert vestover på isoverflaten i Byndalen hurtig skar seg ned, med den følge at materialene i det gamle elveleiet rauset etter ned i sprekken. Istykkelsen måtte her mot vannskillet ha vært minst ca. 80 m da dette skjedde, da dette er eggens største høyde over dalbunnen.

Avsetningsmorenene m.m.

Avsetningsmorenene er jo vanlige foreteelser i områder hvor en bre har forfalt som dødis, og hvor det samtidig har vært rikelige tilførsler av løsmaterialer som dekket til isoverflaten. Et slikt større dødisområde var nettopp det lange, flate vannskillet mellom Orkdal og Oppdal. Den tildels fine, lagdelte kvabb i enkelte av haugene kan nok gi grunn til antagelse om en isdemt sjø, men det er ingen ting som tyder på en jevn fordeling av kvabben. Den opptrer helt lokalt og må være dannet i vannfylte områder av isen under siste fase i avsmeltingen. Etter terrassenes forløp må vannskillet ha blitt isfritt i en tid som svarer omtrent til dannelsestiden for den laveste terrasse, «det horisontale nivå». Breen nedover Bynadalen mot Orkdal hadde etter hvert jevnet seg ut slik at isoverflaten var blitt så godt som horisontal. Dette måtte nødvendigvis medføre at fra denne tid kunne dreneringen langs isens overflate også foregå østover, og gjør en oppdemning på vannskillet lite sannsynlig. Det må være bare et treff at isoverflaten inntok horisontalstilling i den tid vannskillet mot Oppdal ble bart. Men den kraftige utvikling av dette »horisontale nivå» må sees som en delvis følge av at dreneringen vestover nå ble vanskeliggjort at det naturlige vannskillet, og av det samtidig østover langs isoverflaten bare var horisontalt avløp.

Tidfesting av disse hendinger kan bare bli omtrentlig. A. GRØNLIE (1948) har påvist en stegvis avsmelting på begge sider av vannskillet mellom Orkelsjø og Oppdal. Han nevner spesielt Gorsetterrassen fra Ålmdalen like øst for Oppdal som et meget markert trinn i avsmeltingen. (Gorsetterrassen ligger ca. 3 km sydvest for vannskillet vårt). Han holder det for sannsynlig at dette nivå kan korrespondere med Giklingmorenen i Sunndal som antas å tilhøre ra-tiden. Er denne tidfesting riktig, må det nødvendigvis lenge etter ra-tiden ha ligget is i overgangen mellom Oppdal og Orkdalsbassenget.

En nærmere sammenstilling av GRØNLIES iakttagelser i Ålmdalen og Orklsjøtraktene med avsmeltingstrinnene i Bynadalen, og da spesielt med «det horisontale nivå», gjør det klart at for Orkdalens vedkommende smeltet de siste rester av innlandsisen bort i denne dals midtre del. Israndsnivåene vi har fulgt er merker etter den kraftige uttynning som innlandsisen undergikk, og som medførte at fjellpartiene forlengst var isfri da det enda lå igjen breer i dalene og for-senkningene.

Som en supplerende bemerkning til den innledende passus skal nevnes følgende. Det ble i 1913 i «Naturen» ført en diskusjon om alderen av den moskusokseknokkelen som samme år var funnet i en jernbaneskjæring nordligst i Bynas (Gisnas) dal. Funnet ble gjort i lagdelt sand og grus under en 4—5 m tykk, grov morene (drumlins, etter K. O. BJØRLYKKE). H. REUSCH og K. O. BJØRLYKKE hellet til den oppfatning at sandlagene, og dermed hvirvelen måtte være avsatt før siste istid, mens P. A. ØYEN antok at det var en senglacial avsetning, og at den overliggende morene skyldtes et fremstøt av isen i forholdsvis ny tid.

Da denne diskusjon pågikk, kjente man imidlertid ikke til hvordan avsmeltingen egentlig hadde foregått i disse trakter. Etter det foregående har vi sett at ra-tidens brefremstøt eller stagnasjon i avsmeltingen i Oppdals-traktene sannsynligvis svarer til et nivå i 883 m høyde i Oppdal. Altså ca. 250 m høyere enn det noe lengre nord beliggende «horisontale nivå» i Bynas dal (368 m o. h.). Dette nivå går frem til bare noen få kilometer fra finnestedet for hvirvelen, og har en høyde på 144 m over stedet. M. a. o. breen hadde her under ra-tiden en tykkelse på flere hundre meter. Og da det etter MANNERFELT (1940) og MÜNSTER STRØM (1943) ikke gis plass for noen etteristid i høyfjellet, kan heller ikke morenen skyldes et brefremstøt i nyere tid.

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Manuskript mottatt 1. september 1954.

NORSK GEOLOGISK TIDSSKRIFT 34

OM BRE-ISENS AVSMELTNING SYD FOR STORSJØEN I RENDALEN UNDER ISTIDENS SISTE DEL

AV

FREDRIK CHR. A. HUSEBY

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Forord.

Foreliggende avhandling er første del av resultatet av et omfattende undersøkelsesarbeide over dalfyllingen syd for Storsjøen i Rendalen. I denne avhandlingen har jeg behandlet de kvartære former og deres oppståen. Feltarbeidet har pågått i tre somre, nemlig fra 1949 til —51, i forbindelse med kvartærgeologisk kartlegging av kartbladet Stor-Elvdal for Norges Geologiske Undersøkelse, under statsgeolog dr. G. HOLMSENS ledelse. Jeg vil rette en takk til ham, samt til professor O. HOLTEDAHL for den interesse og velvilje de har vist mitt arbeide.

Jeg har også foretatt en mengde med systematiske blokktellinger i feltet, samt gjort mekaniske jordartsanalyser av innsamlet materiale, for å bringe på det rene den petrografiske karakter av disse kvartære avsetninger. Resultatet av dette arbeidet vil bli publisert senere.

Innledning.

TOPOGRAFISK OVERSIKT OVER RENDALEN

Rendalen er en tektonisk anlagt dal, idet dalen danner en nord-sydgående kløft i fjellmassivet langsmed en bruddlinje — den såkalte Rendalsforkastningen — som delvis kan følges langs med dalens østside fra Rødsbakken syd for Storsjøen og nordover til Finstad. Dalsidene er tildels meget steile. Især den østre, hvor også selve hovedforkastningen kan følges. Storsjøens vannspeil ligger 251 m. o. h. Dalbunnen syd for Storsjøen er i gjennomsnitt på 255 m o. h. Høydene av det omkringliggende fjellterreng varierer fra 600 til 800 m o. h. Det morfologiske billedet er vel avrundete former, slik at man har et jevnt, bølgende fjellterreng uten spisse topper.

LITTERATUROVERSIKT OG TIDLIGERE UNDERSØKELSER, SAMT PROBLEMSTILLING

Flere eldre geologer nevner ganske kort litt om de geologiske forhold i den sydligste delen av Rendalen. Således omtaler Keilhau i «Gæa Norvegica» (17, side 371) det blottede grunnfjellsparti øst for Storsjøen, samt «Grauwacken» ved Rena-Elv (side 393) som han betegner som dels kvartsitt-aktig, dels som en rødbrun, finkornet sandstein. Ellers nevner Kjerulf (18, side 20) at «— Rendalen er en rende med bratte vægge», og at den følger «en lang forud beredt linie i det gamle fjeld». På side 21 i samme avhandling beskriver han de geologiske profilene ved Deset og Løset. De samme profiler har han også med i sin «Udsigt over det sydlige Norges geologi» (19, side 110).

Med hensyn til de kvartærgeologiske forhold, skriver KJERULF i 1879 (19, side 28) noen ord om det løse jorddekke ved Løset. Han nevner forekomsten av løse blokker, som han mener må være kommet nordfra. Men den forfatteren som utvilsomt har lagt grunnvollen til forståelsen av landsdelens kvartærgeologi, er SCHIØTZ. Fra hans hånd foreligger der en rekke avhandlinger, hvor han beskriver blant annet blokktransporten i fjelltraktene øst for Storsjøen. Det er særlig problemene angående isskillets beliggenhet han beskjeftiger seg med. Ellers nevner han ganske kort litt om selve dalfyllingen syd for Storsjøen i en av sine avhandlinger (25, side 116—119).

Det generelle landskapsbildet syd for Storsjøen er noen kilometerlange, opptil flere hundre meter brede, flate grusmoer nede i dalbunnen på hver side av Rena-elven. Langs med dalsidene er disse moene flankert av noen høyereliggende grusfyllinger, hvis ytterkant inn mot dalens sentralparti danner en 20—40 m høy skråning. På den måten oppstår der en bred, flatbunnet forsenkning midt etter dalen. De laterale grusfyllinger er meget mektige, og må vel sies å høre med til de mest imponerende kvartære avsetninger vi har her i landet. Særlig er den dødistopografi man finner overmåte storslagen, med tallrike grytehull, hauger og grusåser, hvilket tydelig forteller at det har ligget en dødbre og smeltet ned i slutten av istiden. Jeg har foretatt en detaljert kartlegging av området, men på det foreliggende kartet har jeg for oversiktens skyld gitt en forenklet fremstilling. Hver enkelt overflateform har sin karakteristiske tilblivelseshistorie, som representerer forskjellige stadier i dødbreens nedsmelting. Ved å søke å tolke de enkelte former og se dem i relasjon til hinannen, kan man danne seg et bilde av isavsmeltningens forløp. Dette blir derfor selve problemstillingen.

De glasiale og glasifluviale former.

LATERALE AKKUMULASJONS- OG EROSJONSDANNELSER.

Når en stor dødistunge ligger midt etter et dalføre og smelter vertikalt ned, vil den laterale dreneringen i alminnelighet spille en betydelig rolle, og derfor vil man ofte påtreffe vitnesbyrd om denne i form av laterale spylerenner, og spor etter små laterale issjøer, innen områder hvor man har hatt nedsmeltende dødbreer. Syd for Storsjøen i Rendalen har den laterale dreneringen vært ganske stor. Som det fremgår av det kvartærgeologiske kartet, finnes det et helt system med laterale sandterrasser og spylerenner. På vestsiden, omtrent tvers overfor Oset brer det seg ut en stor sandterrasse, som ligger omtrent 295 m o. h. Materialet består av godt sortert fin sand, og terrassen har en ganske svak helling sydover. Mot vest begrenses terrassen av dalsidens bunnmorenedekke, og mot øst av en skråning som faller ned mot et lavereliggende dødbrelandskap. En slik terrasses oppståen kan bare forklares ved at det har vært demmet opp en liten issjø mellom iskanten og dalsiden, og at sanden er blitt sedimentert i denne sjøen.

Noen hundre meter lenger nord ligger det to mindre terrasser. Den ene ca. 285 m o. h. og den andre (nordligste) ca. 270 m o. h. Disse to er ikke så utpregete som den store øvre terrasse, da overflaten er noe mer uregelmessig, og dessuten har de en ganske annerledes merkbar helling mot syd. Grensen mot de omkringliggende dødbreavsetninger er også noe mer uskarp, men det er ihvertfall tydelig at rennende vann har utformet disse to små terrassene.

Fra den nederste av de tre terrassene kan en stor og markert lateral spylerenne følges i over 2 km's lengde i retning mot Rødsdalen. Den er 50 til 100 m bred. Noen steder er der akkumulert sand, med tydelig lagdeling, mens spylerennen andre steder er uterodert i selve bunnmorenen. Enda lenger nord, på et lavere trinn, er det en liknende lateral spylerenne. Den danner en opptil 200 m bred forsenkning som kan følges fra gården Rød og nordover. Mot øst har denne store spylerennen en meget markert, 1 til 4 m høy kant som danner yttergrensen mot det østenforliggende dødbrelandskap. Omtrent 4 km nord for Rød går spylerennen over i noen sandfyllinger, hvis oppståen antakelig skyldes akkumulasjon av løsmateriale mellom iskanten og dalsiden. Litt lenger nord, øst for Kolbuåsen og på et høyere nivå, ligger en stor lateral sandterrasse av samme type som den lenger syd, i terrenget vest for Oset. Terrassen ligger ca. 300 m o. h. På fig. 1 har jeg tegnet et lengdeprofil av de laterale spylerenner og terrasser på vestsiden av dalen. Man ser hvordan de alle heller nedover fra nord mot syd, samtidig som man får et inntrykk av den vertikale nedsmeltningen, fordi de ligger trinnvis nedover fra syd mot nord. På figuren er også inntegnet en lateral erosjonsterrasse i bunnmorenedekket nordvest for Rød. Den ligger i den bratte dalsiden, ca. 300 m o. h. Fallet sydover er 15 på 1 000 og den er tydelig utviklet som en smal terrasse i en lengde av 200 m.

Rett øst for den store terrassen ved Kolbuåsen ligger der en stor, bred og flatbunnet dreneringskanal, hvor Fredagsengbekken renner før den munner ut i Rena. Materialet består av sand, med avtagende kornstørrelse fra nord mot syd. Kanalen heller mot syd, hvor den går over i den nedre grusflate langs Renas vestside.

Det kan også nevnes at man i dalskråningen på vestsiden flere steder ser små soner med renspylt berg, hvilket muligens kan være forårsaket av smeltevann utmed iskanten på et tidspunkt da isbreen

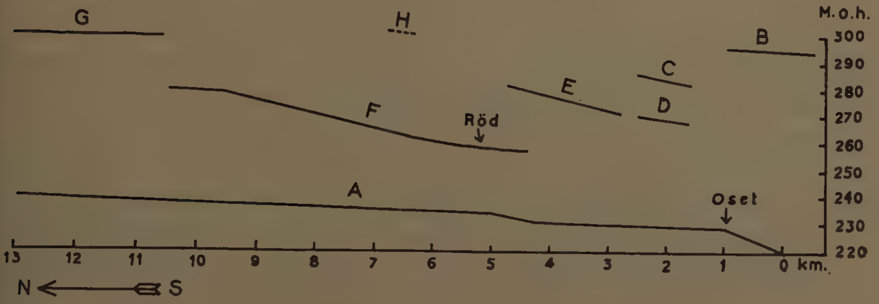


Fig. 1. Lengdeprofil av laterale spylerenner og sandterrasser på vestsiden av Rena.
A. Renas lengdeprofil.
B, C, D: Laterale sandterrasser i søndre del av området.
E: Spylerennen syd for Rødsdalen.
F: Laterale dreneringssystem nord for Rød.
G: Lateral sandterrasse øst for Kolbuåsen.
H: Lateral erosjonsterrasse.

var tykkere. Et sted i terrenget nordvest for Rød ligger der en lang spylerenne, eller en slags gammel elveseng. Den er flere hundre meter lang, og noen steder ligger det rullestein under torvlaget.

Også forholdene på østsiden må omtales, da man her har tydelige spor etter den laterale drenering, akkurat som tilfelle er på vestsiden. Litt nordøst for Rødsbakken er der en lateral spylerenne. Den danner grensen for dødbreavsetningene mot bunnmorenedekket, og har et fall fra nord mot syd. Ved Bjørkerudstuen, sydøst for Deset er der en liten lateral sandterrasse ca. 308 m o. h. (Bestemt ved hjelp av Paulin-barometer). Terrassen er ca. 100 m bred og henimot 800 m lang, og heller svakt mot syd. En litt mindre terrasse ses øst for Hugstjernene. Videre går der en spylerenne over Gjettjernene, nord for Deset kapell. Med Paulin-barometer har jeg funnet høyden over havet ved tjernet til å være 291 m. Også denne spylerennen har et fall fra nord mot syd. Således har vi her et lavere trinn av isens nedsmelting enn det som er representert ved den laterale terrassen syd for Bjørkerudstuen. Som en fortsettelse nordover går en stor og markert spylerenne øst for Slettmotjernet, hvis middelhøyde ligger 300 m o. h.

I feltets sydligste del, over Kjølsetertjernene kan en gammel elveseng følges i flere hundre meters lengde. Elvesengen er oppfylt av rullestein. Det er mulig at Rena har hatt avløp her mellom iskanten og dalsiden, mens isbreen lå som en tynn streng midt etter dalføret. På grusmoen rett vest for elvesengen ligger et felt med store kantete blokker, hovedsakelig av lokal opprinnelse. Muligens er det grovblokket bunnmorene som er kommet frem ved at grusmaterialet er skyllet bort. I nordlig fortsettelse av elvesengen ses tett ved landeveien renspylt berg. Også høyere opp i dalsiden ses flere soner med renspylt berg, slik som tilfelle er på vestsiden.

DØDBREAVSETNINGENES FORMER

Som neste trinn i den kvartære utvikling har vi dannelsen av de enorme dødbreavsetningene i hvert sitt belte langsmed dalsidene. I overflaten består materialet mest av grov sand og grus med rullestein, og man finner en meget storslagen dødistopografi, med utallige pytter og grytehull, samt underlige hauger og rygger. Tiltross for den mangfoldighet av former disse avsetningene byr på, kan man likevel rent skjematisk skille ut følgende hovedformer:

I. *Landskap med store hauger, rygger og grytehull. Markerte former.*

Et slikt landskap finnes syd for Rød, på vestsiden av Rena. Her finner man en mengde med sirkelrunde grytehull. De største har en diameter på henimot 75 m. Andre grytehull har nærmest form som et badekar. Også store hauger, og brede, langstrakte rygger er et dominerende trekk i dette landskapet.

II. *Landskap med hauger, rygger og dumper. Mindre markerte former og mindre dimensjoner.*

Denne typen finnes hyppig på såvel vest- som på østsiden, som f. eks. syd for Søndre Løset. Inntrykket er nærmest et jevnt, bølget landskap med små former. Den sydlige fortsettelsen av landskapet syd for Rød kan med visse tillempninger regnes med til denne typen.

III. *«Pytt-landskap».*

Fra Rød og nordover er det et landskap som jeg vil gi denne betegnelsen. Her har man en småbølget terrengoverflate med små, pyttaktige fordypninger, hvilket antyder at det her har ligget små klumper av dødis, begravet under grusmassene, slik at denne overflaten er oppstått ved den endelige nedsmelting av isklumpene.

IV. *«Dødis-depresjoner«.*

Flere steder i disse dødbre-avsetningene finnes der noen meget store og brede fordypninger, som kan være flere hundre meter lange. Jeg har kalt dem for dødis-depresjoner, da de mer har karakteren av store, uregelmessig formete bassenger enn vanlige grytehull. I bunnen av dem ser man ofte små rygger og mindre grytehull. Den største såkalte dødis-depresjon ligger på østsiden av dalen. Går man opp den bratte grusskråningen ved plassen Småreset, syd for Deset, vil man foran seg se et slags stort grytehull, som ved nærmere undersøkelse viser seg å være en del av en stor dødis-depresjon, som i bukter og viker fortsetter noen hundre meter sydover mot Hugstjernene. Tett ved skogsveien fra Rød og nordover ligger en mindre dødis-depresjon. Hver enkelt av dem må være dannet ved at store, mer eller mindre sammenhengende ispartier har ligget i grusmassene og smeltet ned.

V. *Rygglandskap.*

Vest for Deset, i terrenget omkring Mostjern og Vestertjern har man noen imponerende dødbre-avsetninger. Det mest påfallende trekk her er en stor rullesteins- og grusås, som kan følges ca. 2 km fra Mostjerns nordende og nordover. Den er meget høy og markert, med et stort sett spisst tverrprofil. Enkelte steder hever den seg 30 m opp fra terrenget omkring. Både øst og vest for denne åsen går der noen parallelle åser eller rygger, men av mindre format. Det finnes også hauger, pytter og grytehull i dette terrenget. Således er Melgårdstjern, Mostjern og Vestertjern store, vannfylte grytehull. Rett øst for sistnevnte tjern ligger et meget stort og dypt grytehull, med et lite tjern i bunnen, i hvilket en bekk fra Vestertjern munner ut. Dybden av dette grytehull er anslagsvis 50 m. Et stort grytehull ligger også noen hundre meter syd for Mostjern, med hvilket det står i forbindelse gjennom en lang, smal renne i grusmassene. Trolig er denne rennen dannet av smeltevannsstrømmer på isoverflaten.

Jeg skal gå tilbake til den store grusåsens dannelse. Den laterale dreneringen i forbindelse med en isbres nedsmeltning er jo et over-

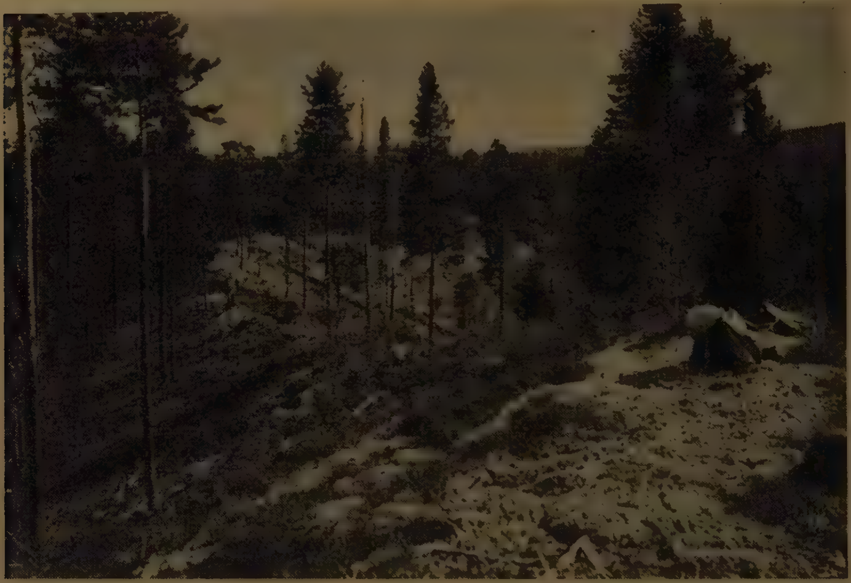


Fig. 2. Grusåsen i Mostjern—Vestertjern-terrenget. Billedet viser åsens nordligste del. Materialet består mest av grus i overflaten. Man ser fra nord mot syd.

flatefenomen, og derfor finner man lett spor etter denne form for smeltevannets avløp. Også på breoverflaten vil der finne sted drenering. Men til slutt vil alt smeltevannet, eller en stor del av dette finne avløp ned gjennom sprekker og hull i isen, og dermed får vi en subglasial drenering, som sikkert går for seg i meget stor målestokk. Av og til vil man innen dødbre-områder påtreffe grusåser. Disse er i mange tilfelle dannet ved at grus og rullestein har fyllt igjen subglasiale tunneller. Men de kan også være dannet ved at grusmateriale er rast ned i åpne sprekker i isen. Som regel vil ethvert spor av denne subglasiale dreneringen være utslettet ved at der tilslutt er blitt avleiret overflatemorene oppå det underliggende materiale.

Grusåsen i Mostjern—Vestertjern-terrenget har stykkevis en kjerne med store rullestein av lokal opprinnelse, nemlig en rød granitt som danner berggrunnen på stedet. Over rullesteinskjernen er det en mantel med grus og små rullestein av fjern opprinnelse. I lengderetningen har grusåsen et buktet og uregelmessig forløp. Tverrpro-

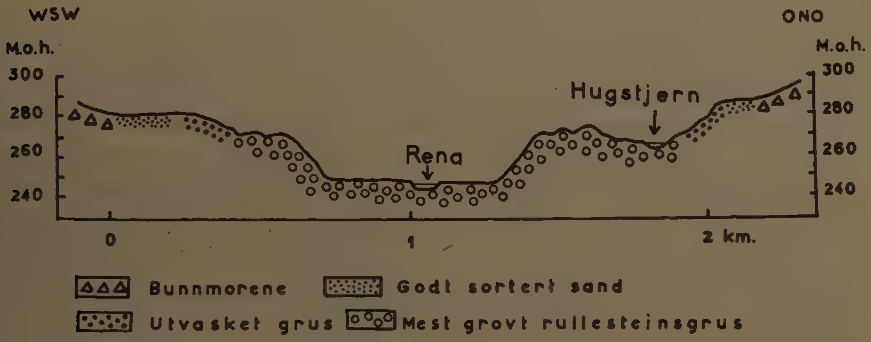


Fig. 3. Dal-tverrprofil syd for Deset. På dette profil ser man en bred «kanal» eller fordypning midt i dalen med en flat grusslette i bunnen. På hver side hever seg en høy, bratt kant med noen grusfyllinger innenfor (dødbreavsetninger). Disse går jevnt over i noen høyereliggende, laterale sandterrasser.

filet er meget spisst, hvilket muligens må oppfattes som at åsen er dannet ved akkumulasjon av rullestein i en lukket sprekk eller tunnel, med derpå følgende sammenstyrtning av tunneltaket og avleiring av det grusmaterialet som lå oppå isen. Var åsen blitt dannet ved avleiring av materiale i en åpen sprekk, hadde tverrprofilet neppe vært så spisst. (Jfr. MANNERFELT 21, side 145—149). På fig. 2 ser man et utsnitt av åsen rett øst for Vestertjern.

VI. *Utvaskete overflateformer.*

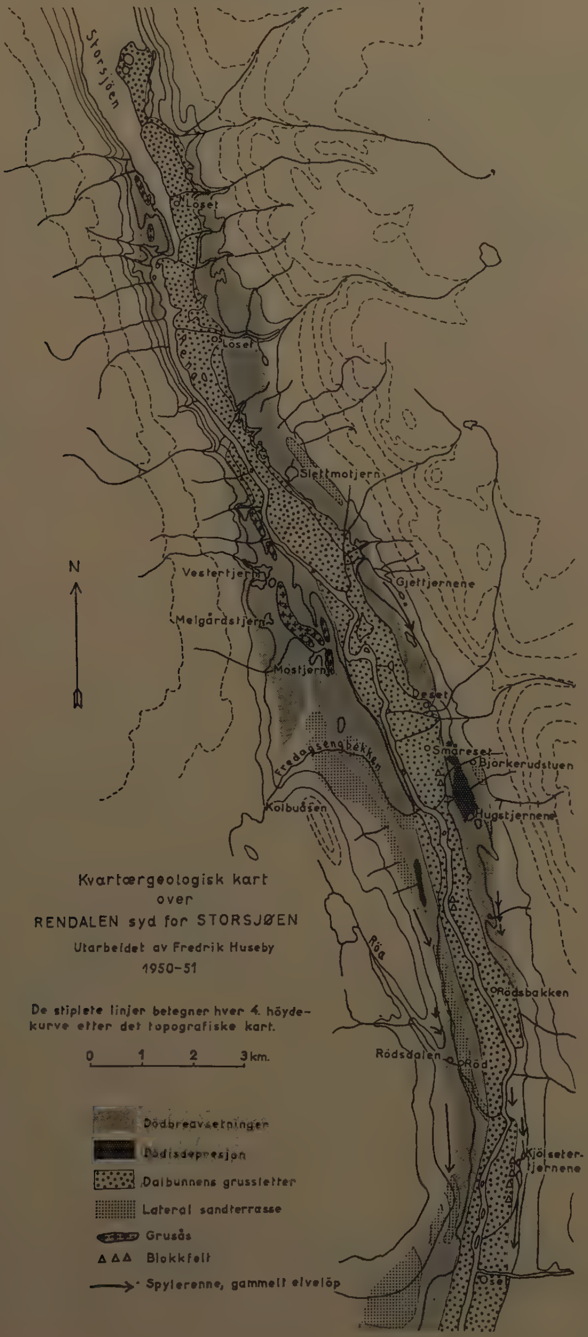
Langsmed siden av de laterale sandterrasser og spylerenner, inn mot dalens midtre del, har man jevnt, utvaskete overflateformer. Det ser nærmest ut som om rennende vann har glattet ut de ellers nokså markerte former man finner i dødbreavsetningene. På fig. 3 har jeg tegnet et dal-tverrprofil litt syd for Deset. Profilet illustrerer ganske godt forholdene innen det undersøkte området. De mektige dødbreavsetningene langsmed dalsidene har ganske utpregete overflateformer. Lenger inn mot dalsiden får de en mer utvasket og utjevnet karakter. inntil de går over i en høyereliggende, lateral sandterrasse. Midt etter dalen trer denne brede forsenkningen ganske klart frem.

VII. *En intraglasial morene ved Rød.*

I området ved gårdene Rød og Rødsdalen har man et småkupert morenelandskap, med hauger og pytter. Formene har en litt annen karakter enn de man ellers finner i dalføret. Man kan nærmest gi dem betegnelsen små og markerte former. Materialet består av skarpkantet grus og steinmateriale hovedsakelig av lokal opprinnelse, nemlig rød sparagmitt og Ekre-skifer, som tilsammen utgjør mer enn halvparten av steinmaterialet. I de typiske bunnmorener er nesten alt steinmaterialet av lokal opprinnelse. Ettersom materialet i de øvrige dødbre-avsetninger overveiende består av grus og rullestein av fjern opprinnelse, er jeg av den oppfatning at dette må være en såkalt intraglasial morene. Den ligger også tett inntil den mot nord oppstikkende berggrunn, og befinner seg således i ly for selve hovedstrømretningen av breisen. (Kfr. AHLMANN 1, side 327—341).

OM DANNELSEN AV DEN STORE FORSENKNINGEN MIDT ETTER DALFØRET

Et viktig topografisk trekk i Rendalens sydligste del er denne brede, flatbunnete forsenkningen midt etter dalen, som fremkommer på grunn av de høyereliggende grusfyllinger langs dalsidene. Av litteraturen fremgår at man har liknende forhold andre steder. T. F. JAMIESON (16) beskriver i siste halvdel av forrige århundre denslags dannelser i skotske dalfører, med laterale sand- og grusmasser og en stor hulning eller forsenkning midt i dalen. Om de såkalte «gravel terraces» skriver han (side 332): «I am of the opinion — — — that these deposits have been for the most part accumulated during the gradual retreat and melting of the later glacier.» På side 333 beskriver han hvorledes han tenker seg denne traug-formige forsenkningen eller «channel» dannet av en istunge. Alt løsmaterialet tenker han seg ført ned langs dalsidene av vannstrømmer, og i retning av den «channel» hvor elven nå renner. »— but when the channel was occupied by a glacier this debris would be arrested by the mass of ice and lodge in the depression between the glacier and the hill. This hollow would therefore be gradually filled up and might be traversed at times by streams of water. When the glacier melted, the mass of stuff resting against it would lose its support and fall down in a steep slope, thus giving rise to the terraced banks we now find».


Storsjöen
Löset
Löset
Slettmotjern
N
Vestertjern
Gjettjernene
Melgårdstjern
Mostjern
Deset
Fredagsengbekken
Småreset
Björkerudstuen
Kolbuåsen
Hugstjernene
Kvartærgeologisk kart
over
RENDALEN syd for STORSJØEN
Utarbeidet av Fredrik Huseby
1950-51
Röa
Rödsbakken
De stiplete linjer betegner hver 4. höydekurve etter det topografiske kart.
0 1 2 3 km.
Rödsdalen
Röd
Kjölseter-tjernene
Dödbreavsetninger
Dödisdepresjon
Dalbunnens grussletter
Lateral sandterrasse
Grusås
Blokkfelt
Spylerenne, gammelt elvelöp
Öset

Liknende forhold med laterale sand- og grusmasser på hver side av en fordypning, som følge av en isbres nedsmelting, finnes også beskrevet av norske geologer. Således omtaler O. HOLTEDAHL forholdene ved Dal stasjon på Romerike, og ved Grundset i Østerdalen, samt Elverum (14, side 43 og 94). Han sier at Hersjø—Dal-forsenkningen på Romerike primært skyldes nedsmeltningen av en tungeformet dødis, på hvis to sider en betydelig sand og grussedimentasjon fant sted. Det kan også henvises til TORE SUNDS iakttagelser fra Dørålseter i Rondane (27, side 183).

Når det gjelder dannelsen av denne «hulningen» midt etter Rendalen, er jeg av den oppfatning at den er oppstått på grunn av en isbre som har ligget midt etter dalen og smeltet ned. Dersom den primære årsaken skulle være rennende vanns erosjon i store grusmasser som måtte forutsettes å ha fyllt hele dalen, måtte vi for det første vente å finne de vekkførte mengder av grus nedover i Østerdalen. Dernest ville det vært rimelig om denne «hulningen» hadde vært nedskåret i løsavleiringene med jevne og rette sider, slik som litt steile elvebredder i grusmasser gjerne blir. Når man står nede i dalbunnen syd for Deset, vil man riktignok ha inntrykk av å befinne seg i bunnen av en slags kjempemessig kanal, hvor de laterale grusfyllingers kanter inn mot dalens midtre del danner sidene. Stykkevis går de nemlig rettlinjet i flere hundre meters lengde, og er tydelig påvirket av rennende vann. som jeg kan tenke meg har strømmet mellom den stadig uttynnende isbreen og grusavsetningene langs dalsidene. Men noen steder går kantene i små viker, og kan til og med gjøre veldige innbuktninger. Andre steder går de høyereliggende, laterale grusavsetninger jevnt over i de nedre grusflater langs elven, som flere steder er oppfylt av grytehull. Det er særlig nord og syd for S. Løset man finner disse grytehull. Etter mitt skjønn taler dette for at den primære årsaken til dannelsen av «hulningen» midt etter dalen skyldes en nedsmeltende isbre som er blitt delt opp i mindre dødisklumper. Den endelige utformingen skyldes smeltevannsstrømmer som har skyllet over grusflatene i dalbunnen.

STORSJØENS ISRANDTERRASSE

Ved sydenden av Storsjøen ligger det en pen, liten israndterrasse, som danner avslutningen mot nord av de kilometerlange grusflatene i dalbunnen. Israndterrassen er oppfyllt av en mengde store og små grytehull. På en liten tange som stikker ut i Storsjøen ligger to ganske store tjern. Det er vannfylte grytehull, og de er omtrent sirkelrunde. De ses tydelig fra landeveien på østsiden. På vestsiden ligger to terrasser trinnvis over hinannen. Den nederste ligger ca. 15 m og den øverste ca. 35 m over Storsjøens vannspeil. Begge to er oppfyllt av grytehull.

TILBAKEBLIKK: OVERSIKT OVER DEN KVARTÆRE UTYIKLING

Det viser seg at det langt oppe i dalsidene, foruten i det høyereliggende fjellterreng på hver side av Rendalen finnes relativt tynne bunnmorenedekker med et utpreget monomikt, skarptkantet blokkmateriale fra den underliggende berggrunn, mens det i dalens lavereliggende deler finnes anriket enorme grus- og rullesteinsmasser av utpreget fjerntransportert karakter. Det er et problem for seg hvorfor man har den største opphopning av løsmateriale i den lavestliggende delen av dalføret. Grunnen til at man har dette forholdsvis sparsomme bunnmorenedekket i det høyereliggende fjellterreng, er kanskje den at isen har beveget seg over en relativt jevn fjelloverflate uten oppstikkende topper av betydning, og at materialtilførselen vesentlig har foregått fra den underliggende berggrunn og til isens underste del. I selve dalen er det tenkelig at materialtilførselen for det meste har foregått fra de steile dalsidene. En annen ting som kanskje kan ha bidradd til den enorme opphopning av løsmasser nede i dalbunnen er det forhold at mens isen smeltet seg vertikalt ned, ble det materialet som var blitt avleiret høyere oppe i dalsiden etterhvert spylt videre nedover mot dalbunnen. Men det ligger dog utenfor problemstillingen her.

Når det gjelder selve isavsmeltningen, kan man i grove trekk skille ut følgende stadier:

1. Lateral drenering. Dannelse av laterale sandterrasser, som følge av små issjøers oppdemning mellom breen og dalsiden. Dannelse av laterale spylerenner.

2. Fremsmeltning og avleiring av morenemateriale. Dannelse av de store dødbreavsetninger i hvert sitt belte langsmed dalsidene.

3. Endelig nedsmelting av en tynn istunge midt etter dalen. Dannelse av en bred, flatbunnet forsenkning der hvor istungen har ligget.
4. Dannelsen av israndterrassen syd for Storsjøen.

Ravinene innen området

En ting som er verd å henlede oppmerksomheten på, er en mengde med raviner innen området. De skjærer seg gjennom denne karakteristiske bratte kanten, som på hver side av dalbunnens grusflater danner ytterkanten av de innenforliggende dødbreavsetninger, og ligger transversalt i forhold til dalførets retning. Vanligvis er ravinene flatbunnet eller U-formet og kan være opptil flere hundre meter lange. Ravinedannelsen og dens årsaker har jeg ikke studert nærmere. Muligens kan årsaken til deres oppståen i flere tilfelle være en kombinasjon av flytjord og vannerosjon. I alle tilfelle må ravinene være dannet under avsmeltningstiden, da man ikke finner noen form for opphopning av materiale utenfor deres munninger.

Isskillet. Isens gradient.

Beliggenheten av isskillet innen dette østlige område av Norge er et problem som har beskjeftiget flere geologer. Særlig har SCHIØTZ arbeidet med dette (23, 24, 26). Å utrede beliggenheten av isskillet ligger utenfor rammen her, men jeg vil gjerne komme med en del bemerkninger.

Ifølge G. HOLMSEN (9, side 78—83) finnes det seter så langt syd som til Mistra, ved Storsjøens nordende. Han refererer også til noen høydeangivelser på seter ved Akre og Kvernnesvola, etter A. HANSEN (Archiv for Mat. og Naturvidenskab, Bind 15, 1892, side 89), og mener at disse seter utgjør de sydligste sporene etter Nedre Glåmsjøs strandmerker. Sommeren 1949 iakttok jeg sammen med statsgeolog P. HOLMSEN og cand.mag. GERD VOGT en nordoverhellende spylerenne i dalsiden nord for Lomnesseter, ved Lomnessjøens østside, ca. 600 m o. h. Dette tyder på at isoverflaten hadde en helling nedover fra syd mot nord på dette stedet, mens den syd for Storsjøen hadde en helling sydover. Ifølge mine egne målinger har de laterale spylerenner syd for Storsjøen en gjennomsnittlig helling sydover av 4 : 1 000.

Dette antyder at isoverflaten må ha hatt omtrentlig samme helling i samme retning.

Når det gjelder isskillets beliggenhet over Rendalen, forteller blokktransporten endel interessante ting. Samme sommer iakttok jeg sammen med frk. VOGT en anortosittblokk i grustaket ved Hornset, nord for Lomnessjøen. Dette stedet ligger ca. 5 km nord for nærmeste lokalitet hvor denne bergart finnes i fast fjell, nemlig Ottlauakomplekset. Dette bergartskompleks er forøvrig nærmere beskrevet av K. O. BJØRLYKKE (3). Funnet tyder på en nordovergående brebevegelse her. I de løse avsetninger syd for Storsjøen hvor jeg har drevet omfattende og systematiske blokktellinger, har jeg ikke kunnet påvise blokker fra kjente lokaliteter nord for Storsjøen. De bergartsbruddstykker som finnes i løsmaterialet syd for Storsjøen, og som er de nordligst kjente, stammer fra Valsjøberget (øyegneis) på Storsjøens østside, samt fra et område med presset, lys sparagmitt på vestsiden, syd for Ottlauakomplekset (Mora-sparagmitt).

Sammenfatningsvis kan det sies at disse kjennsgjerninger taler for at isskillets under istidens siste del har ligget over Rendalen omkring Storsjøens nordre og Lomnessjøens søndre del.

Et spørsmål av interesse er Nedre Glåmsjøs uttapning gjennom Jutulhugget, som ligger mellom Glåmdalen og Tyldalen, og i hvilken grad disse enorme vannmassene har satt sine spor sydover Rendalen. Det ville være rimelig å finne spor enten i form av erosjon eller akkumulasjon av løsmateriale. som følge av en slik stor tapningskatastrofe. De mektige grusavsetningene syd for Storsjøen bærer ihvertfall ikke på noen måte spor av en slik stor vannflom. Dette gjelder også den store forsenkningen midt i dalen, hvis dannelse primært må skyldes nedsmeltningen av en sentralt liggende isbre.

Forklaringen på at man ihvertfall tilsynelatende ikke finner sporene sydover Rendalen etter Nedre Glåmsjøs uttapning, er kanskje den at Rendalen fremdeles var oppfylt av en isbre mens uttapningen foregikk. Det er nemlig en vanlig oppfatning blant geologer at Rendalen ble isfri før Glåmdalen. Under uttapningen har isåfall flomvannet funnet vei i sprekker og subglasiale tunneller, og på den måten finner man ikke noen direkte spor etter denne mektige tapningskatastrofe. Ihvertfall er vi i dag ikke istand til å finne sporene etter denne mektige flommen som vi må forutsette har funnet sted i Rendalen.

SUMMARY.

The present publication is the result of glacial-geological investigations south of lake Storsjøen in Rendalen, during three summers. Rendalen is a tectonic valley, with a well developed fault along its east side, the so-called fault of Rendalen. Formerly some geologists have roughly touched on the geological features, i. e. the igneous and the sedimentary rocks and the stratigraphy of the latter. Most interesting, however, are the quaternary deposits, which are among the most imposing in Norway. Their origin are due to the melting of a big dead-ice in the latest period of the Ice-age.

The glacial-morphological features consist of some large deposits of sand and gravel along each side of the valley. In the middle part of the valley these deposits fall down in a steep slope, about 20 to 40 meters high, against a flat gravel terrace in the bottom of the valley. This terrace is several kilometer long and hundreds of meters broad. In this way there is a great «channel» along the central part of the valley.

When a glacier is melting vertically down, the lateral drainage will be considerable. Within the explored region there are many lateral drainage channels and lateral sandterraces. The latter tell about the existence of small icelakes, dammed between the ice margin and the valley-side. The drainage channels are sloping southwards.

During the gradual retreat of the glacier, large masses of sand and gravel were deposed alongside the lateral sand-terraces and the drainage channels. The dead-ice topography of these deposits is grand, with kettles, eskers and mounds. There is a big, 2 kilometer long esker at the west side of the valley, originated by the accumulation of boulders and gravel in a sub-glacial tunnel.

Noticeable is the great «channel» along the middle part of the valley. In the latest phase of the melting-period the glacier shrunk to a little string. When it finally melted down, this «channel» was formed in the place former occupied by the shrunken glacier.

At the south-end of lake Storsjøen there is a little gravel terrace with kettles. The biggest of the kettles are filled with water.

There are many ravines within the region, but they are only roughly

explored. Probably they have been formed as a combination of solifluction and water erosion.

The lateral drainage channels mentioned have an average gradient of 4 : 1000 southward, which indicates the surface of the glacier sloping this way during the Ice-age. Also the transportation of erratics proceeded this way. On the other hand there is a lateral drainage channel by the lake Lomnessjøen, north of Storsjøen, sloping northward, which tells that the surface of the glacier in this place had another direction of slope. The transportation of erratics north of lake Storsjøen seems to have been from south to north. As to these facts I am of the opinion that the Ice-shed passed Rendalen between Storsjøen and Lomnessjøen.

During the last time of the Ice-age there was a gigantic draining of Nedre Glåmsjø ice-lake through Jutulhugget, a great defile between Tyldalen and the neighbouring valley Østerdalen, with the waterflows streaming downward Rendalen. There are no marks from such a flood, perhaps due to the possibility of Rendalen being occupied by a glacier at this time.

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G.F.F. = Geologiska Föreningens Förhandlingar.
N.G.T. = Norsk Geologisk Tidsskrift.
N.G.U. = Norges Geologiske Undersøkelse.
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Manuskript mottatt 11, mars 1954

OM JORDARTEN KVABB OG DENS OPPTREDEN SYD FOR STORSJØEN I RENDALEN

AV

FREDRIK CHR. A. HUSEBY

Abstract. In the valleys of Rendalen and Østerdalen there is a soil type called kvabb. Kvabb is a silt which consists of small particles washed out of the moraine. Due to the capillarity and the strong infiltration of water under given conditions soil slips are common in the kvabb deposits.

I Rendalen og Østerdalen opptrer det en jordart som kalles for kvabb. K. O. BJØRLYKKE (2) skriver allerede i 1896 om forekomsten av denne jordart ved gården Løset i Rendalen.

I årene 1949—51 gjorde jeg en del undersøkelser over kvabben og dens opptreden i de nevnte dalfører, og særlig i Rendalen. Kvabb er en mojord med bestemte fysikalske egenskaper, og den består vesentlig av fraksjonene mo og mjele, hvilket vil si partikler med diameter mellom 0,2 og 0,002 mm ifølge Atterbergs skala. Ute i naturen er kvabben blå-gråaktig, og har ofte brune striper. I tørr tilstand blir den lett hård og slår sprekker. Ved oppsmuldring ser den ut som et gråhvitt, melliknende støv. Den opptar lett vann og blir deigaktig og flyter utover ved rystelser eller slag, samtidig som den avgir en del av sitt vanninnhold. I Rendalen opptrer kvabben på to måter: Enten som valker og linser oppå bunnmorenedekket i dalsidene, eller i dalbunnens grusavsetninger hvor den forekommer i horisontale lag eller som skiveformete avsetninger i bratte jordskråninger. Oppe i dalsidene ser man ikke så sjelden linser av kvabb som stadig siger nedover bakke. Det er særlig der hvor det finnes veiskjæringer eller hvor vegetasjonsdekket på en eller annen måte er fjernet det har lett for å danne seg slike ansamlinger av kvabb.

Fra trakten omkring Deset, syd for Storsjøen har jeg endel mekaniske analyser av prøver fra kvabbforekomster. Noen resultater er gjengitt i siktekurvene på figuren. Kurve I viser den midlere mekaniske sammensetning av fire utvalgte kvabblinser i østre dalside. De har en ganske annen usortert karakter enn man skulle vente etter utseendet i naturen. Innholdet av mo og mjele utgjør i gjennomsnitt ca. 60 vektsprosent. Kurve II er fra en prøve som ikke er tatt med i middelverdikurven, da den skiller seg skarpt ut fra de øvrige, både med hensyn til mekanisk sammensetning og opptreden i naturen. Den er tatt fra en liten grop langt nede i dalsiden, og den består nesten bare av mo og mjele. Derfor kan den nærmest betegnes som en «ren» kvabb.

I de store grusavsetningene nede i dalbunnen vil man av og til se horisontale lag av kvabb i skjæringer og grustak. Tykkelsen kan være fra noen få cm. og opp til et par dm. Men hyppigst sees kvabben i jordskråninger, hvor den ligger som en mantel utenpå det øvrige jordartsmateriale. Som regel er kvabben på disse stedene skiveformet med skivene hellende nedover bakke, hvilket tyder på at den er seget utfor. Kurve nr. III er middelverdikurven for prøver tatt ut fra 6 kvabbforekomster i bakkeskråninger syd for Deset. Fraksjonene mo og mjele er til stede i overveiende mengde, slik at man her kan snakke om «rene» kvabbforekomster. Det later til at kvabben er mere usortert oppe i dalsidene, mens den i dalbunnen har en tendens til å være ensartet med hensyn til kornfraksjoner. Dog finnes det unntagelser. Som eksempel har vi kurve nr. IV. Den viser sammensetningen av en prøve tatt ut fra en kvabblinse i et grustak rett syd for Deset kapell. Kvabblinsen har en vertikal skivestruktur, og ser på stedet ut som en «ren» kvabb, men som siktekurven viser er den meget usortert og minner om en morenes siktekurve. Den vertikale skivestruktur er antakelig oppstått på grunn av glidninger, og under disse bevegelser kan det tenkes at kvabben er blitt oppblandet med grovere materiale, selv om ikke siktekurven viser at to lag er blitt blandet sammen.

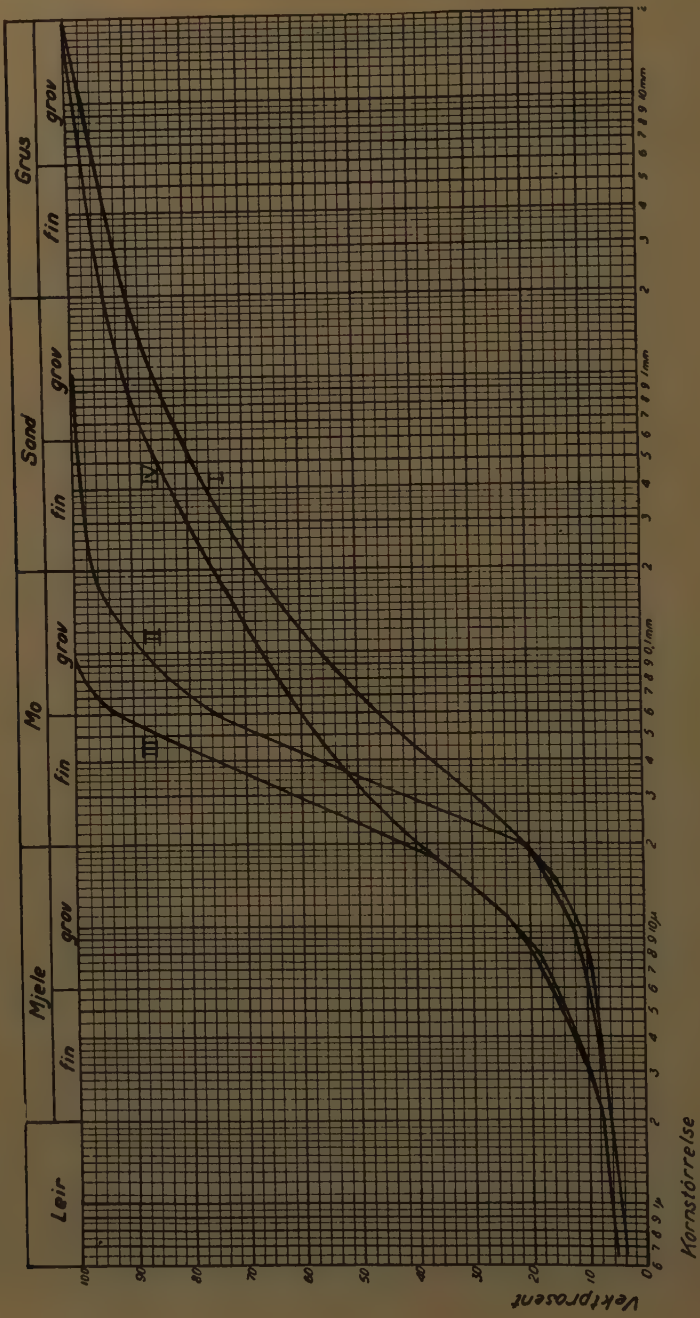
Etter den måten kvabben opptrer på i naturen, er den en sekundært avsatt jordart dannet ved at finmateriale er blitt vasket ut av moreneavsetninger. Om våren og i nedbørrike perioder foregår det en stadig utvasking av de finere bestanddeler i morener, hvilket gir seg tilkjenne ved små strømmer av kvabb i bakkeskråninger, samt belegg med kvabb på loddrette vegger i grustak og veiskjæringer.

Dette belegget har ofte de underligste mønstre og kan i enkelte tilfelle minne litt om bikaker.

Med hensyn til geotekniske egenskaper er det en kjent sak at kvabb er en telefarlig jordart, da den har evne til å suge opp store mengder vann. Under tiningen om våren dannes det store mengder overskuddsvann som gjør at jordarten går over i en nærmest flytende tilstand. Kvabben har nemlig den egenskap at den ved et visst vanninnhold går over fra fast til flytende eller vellingaktig tilstand. Dette vanninnholdet kalles for flytegrensen. Jeg har bestemt vanninnholdet ved flytegrensen for samtlige innsamlete kvabbprøver, og det ligger på ca. 30 vektsprosent av tørrvekten. Kvabben mangler plastisitet og skiller seg på den måten fra leire. Grunnen til at kvabb flyter utfor bakke ved vanninfiltrasjon er at vannhinnene rundt mineralkornene nedsetter friksjonen. Når den ved støt og slag avgir vann, må det antakelig være fordi kornene rykker tettere sammen slik at en del av porevannet presses ut. Under mikroskopet viser det seg at mineralkornene hovedsakelig består av litt kantete kvartskorn.

Der hvor man har telefarlige jordarter som f.eks. kvabb, kan det ofte oppstå tuer. Et slikt fenomen sees ved gården Småreset syd for Deset, hvor det ved foten av en bakkeskråning ligger en avsetning med kvabb oppå grus. Tuedannelsen kommer antakelig istand på den måten at jordartens struktur forandres ved gjentatt frysing og tining. Alle tuene er dekket med et lag av reinmose, slik at marken får et vorteformet utseende fordi vegetasjonen mangler mellom tuene. At vi får en slik mark med mose oppå tuene er vel ikke så enkelt å gi en rimelig forklaring på. Mosen virker jo varmeisolerende, så frosten må ha trengt ned i jorden der hvor mosen mangler. Derved har det kanskje dannet seg iskaker under de bare flekkene som så har skjøvet mineralkornene inn under moseflekkene, hvorved disse er blitt presset oppover, og dermed har tuedannelsen vært igang.

Foruten å være telefarlig er kvabben også rasfarlig, idet den lett kan gi etter og rase ut i bratte skråninger når vanninnfiltrasjonen blir stor. Derfor ser man ofte større og mindre rassår i jordskråninger i Rendalen, og det er særlig om våren utrasningene finner sted. Et stort rassår ligger vest for Deset hvor en 30 m høy grusbakke skråner steilt opp fra elvebredden. Ytterst i bakken står en skiveformet kvabb, med skivene hellende nedover. Midt i bakken sees et friskt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Kornstörrelse

rassår, som anslagsvis er 20 m høyt og 30 m bredt. Det er rast ut minst 5 000 kubikkmeter masse på stedet, og en tømmervei som går ovenfor raset er ufarbar, fordi endel av veiens ytterkant er glidd ut. De andre rassårene jeg har iakttatt er av mindre format, men de opptrer alltid der det finnes kvabb. Utrasningene finner særlig sted i veiskjæringer hvor vegetasjonsdekket er fjernet, og derfor bør man alltid foreta jordartsundersøkelser før man bygger vei innen områder hvor kvabben er en hyppig opptredende jordart.

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RASET I MODALEN
14. AUGUST 1953

AV

NIELS-HENR. KOLDERUP

Abstract. On August 14th, 1953, at 2.30 p. m. a castrophe struck some farms of Nedre Helland, Modalen, Hordaland fylke (county).

The proceedings were the following:

1. A piece of rock, estimated to 24 000 tons, fell vertically about 200 m and hit a rock-strewn slope. The slope was about 30°.

2. Immediately the talus began to move, and 300 000 tons were pushed forward, covering 45 000 m² of cultivated land, situated on a large terrace. Two farms got their houses crashed, but no person was injured.

3. This talus dammed the brook that used to drain the terrace, and in rainy weather a lake covers large parts of cultivated land.

4. The water of this lake, having no drain, sunk into the deeper parts of the terrace, soaked the fine sand, and caused small landslips along the edges of the terrace.

This is a very unique accumulation of accidents, but it may happen again in narrow valleys in mountaineous regions.

14. august 1953 kl. ca. 14½ falt en fjellblokk ned fra Storfjellet nord for nedre Helland i Modalen herred, Hordaland fylke. Da katastrofen foregikk ved høylys dag, var alle mennesker på stedet vitne til den. For undersøkelsene og for denne fremstilling var det særlig verdifullt at topograf ved Norges Geografiske Oppmåling, kaptein HJ. SKAAR, var blant disse øyenvitner. Han skrev ned en beretning, og han målte straks opp rasets dimensjoner. Han har dessuten tegnet et kart over stedet i 1:15 000, med ekvidistanse 10 m (fig. 2), slik at det på dette grunnlag lot seg tegne et nøyaktig profil over rasstedet (fig. 3). Jeg vil få takke kaptein HJ. SKAAR på det beste for hans interesserte medarbeiderskap.

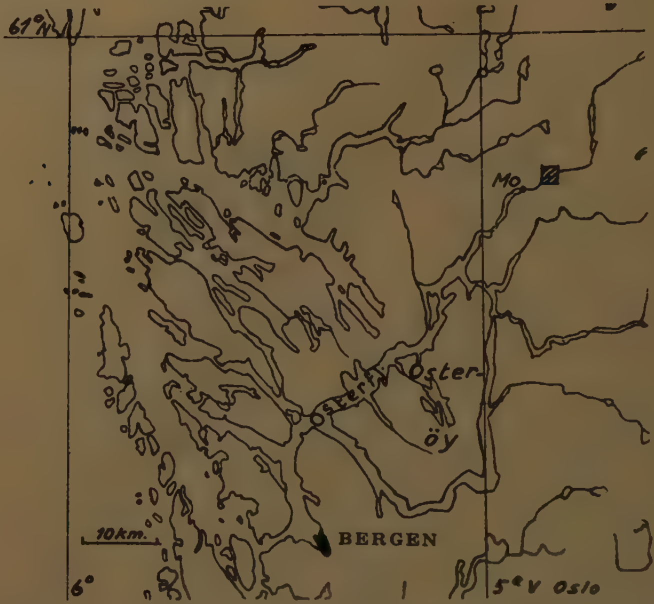

Fig. 1. Det skraverte felt viser området for detaljkartet fra ras-stedet ved Helland i Modalen (fig. 2).

Situasjonen er vist på fig. 1. Den trange Mofjord, 4 km lang og 5—700 m bred, står i sydvest gjennom Mostrømmen i forbindelse med Osterfjorden. Fra fjordbunnen i nordøst ved Mo og Otterstad skjærer Modalen seg inn i fjellmassene. 5 kilometers vei opp i dalen ligger gården nedre Helland med 6 bruk på en terrasseflate, ca. 50 m o.h. Terrassen har ca. 500 mål jord, hvorav særlig de langs fjellsiden har et bra jorddekke. Terrassen er for det meste overdekket, så dens bygning i detalj er ikke kjent. Men etter leilighetsvise snitt kan man slutte at den høyest oppe vesentlig har hardpakket, noe rustfarget grus med nevestor stein. Nedover blir materialet finere, og langs elven er det observert fin sand, pussesand. Terrassen ble før raset drenert ved en flombekk, som hadde gravd seg et ca. 10 m dypt far i sydlig retning. Hele terrassens overflate heller svakt mot bekkefaret, slik at den er høyest mot elven i syd.

Fjellsiden i nord for terrassen er først kledd med storsteinet ur, med helningsvinkel omking 30°, eller 2:1. På rasstedet gikk uren

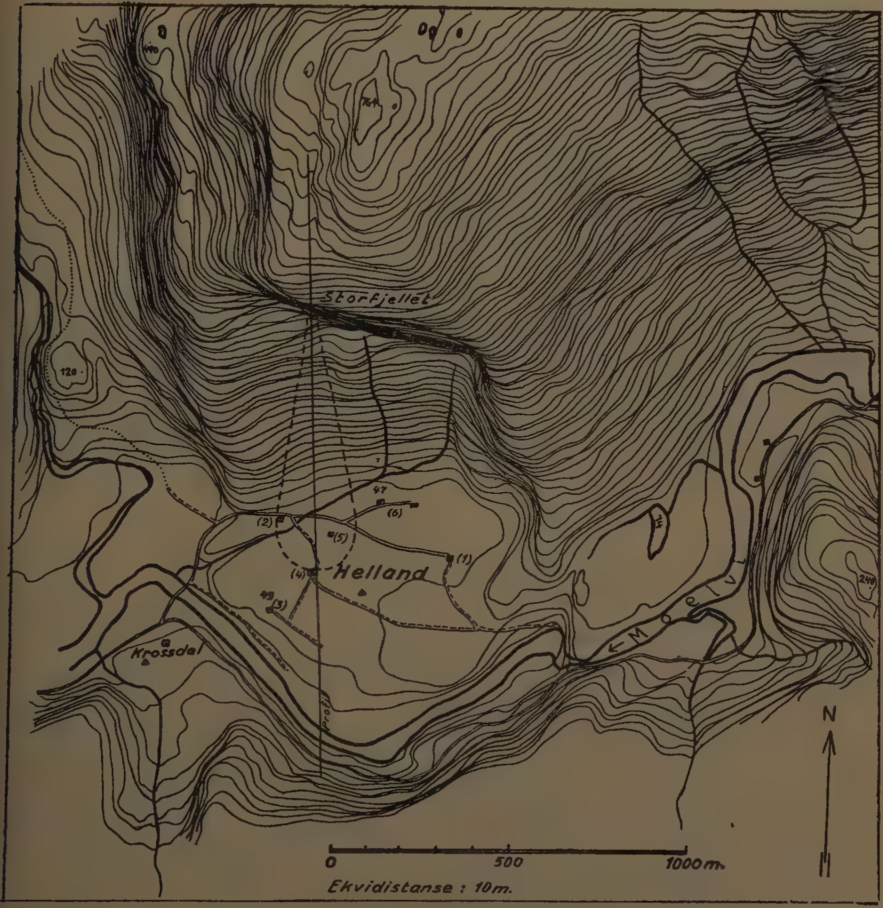

Fig. 2. Kart over området ved nedre Helland. Inntegnet utbredelsen av raset og posisjonen av profilet (fig. 3). Tallene i parentes er bruksnummere.

opp til 328 m o. h., eller 180 m over terrassen. Derfra står det en henimot loddrett fjellvegg til 524 m o. h. Disse tallene gjelder bare for selve rasstedet. Lenger østover rekker ikke uren så langt opp. Lengst i øst er det et parti som kalles «Storstovo». Her heller fjellet utover uren, så man står tørt i regnvær. Fjellsiden har en ganske frisk bruddflate, så her har et fjellparti falt ut forholdsvis nylig. Hele uren langs nordsiden av terrassen er selvsagt materiale som er falt

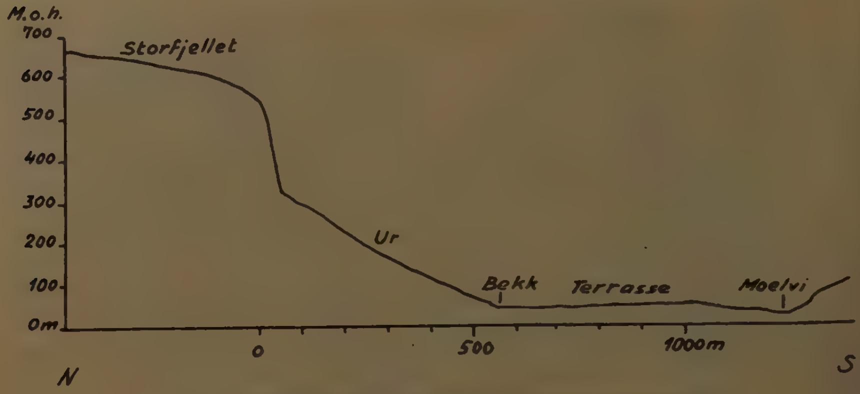

Fig. 3. Profil gjennom ras-stedet Storfjellet-Moelvi.

ned fra fjellsiden. Det er ikke avrundete moreneblokker i den, men bare skarpkantete ur-blokker. Det var på sine steder meget vegetasjon i uren, så det var ikke så lite jord mellom steinene.

I påsken 1953 gikk det et mindre ras fra Storfjellet. På den tiden var det avvekslende tøvær og frost. Omkring midten av august var det varmt om dagen og forholdsvis kjølig om natten, så det var en ganske stor temperaturforskjell i løpet av et døgn. Natten til 14. august og utover formiddagen falt det stadig steinblokker fra Storfjellet ned i uren, og kl. 14½ kom så den store steinblokken styrtende. Den falt i praktisk talt fritt fall nedover i uren med et øredøvende brak, og deretter ble hele uren innhyllet i en sky av gråhvit steinrøyk. Først da den hadde lagt seg, kunne man få øye på skadens omfang.

Skaar målte bruddflatens høyde til 48 m, og beregnet vekten av blokken til 24 000 tonn. Da denne slo ned i uren, satte den uren i bevegelse nedover, og en masse stein og jord skred utover terrassen, trengte 200 m frem på den, fylte bekkefaret som går på tvers av rasets retning, og dekket 45 mål jord. Dekket av ur på terrassen var mellom 5 og 10 meter høyt, og omkring 200 meter bredt. Hele dekket er meget skarpt begrenset. På de fleste steder reiste dekket seg bratt opp fra terrasseflaten, og de stein som var kommet utenfor var neppe større enn et mannsløft. Det var slike som var slått av de større blokkene når de støtte mot hverandre i fallet. Kaptein Skaar har beregnet vekten av blokken til 24 000 tonn, og den fremskjøvne mas-

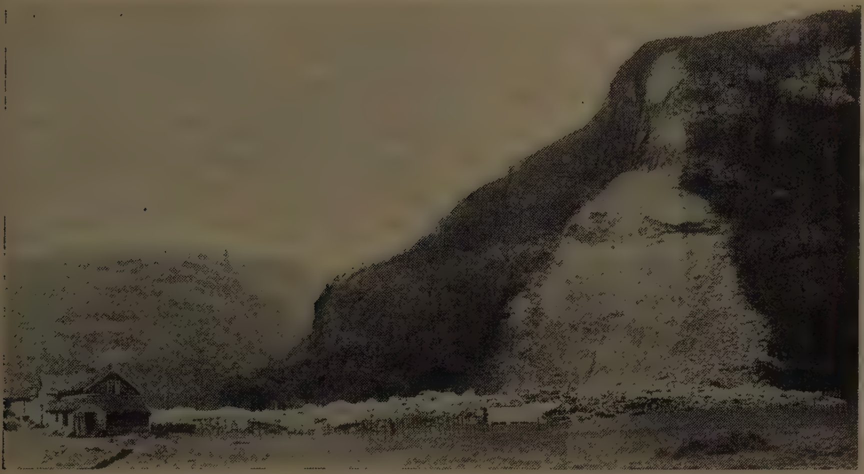

Fig. 4. Raset i Modalen 13. august 1953 sett fra bruk nr. 4 på gården nedre Helland.

sen til 300 000 tonn. D.v.s. den fremskjøvne massen er ca. 12 ganger så stor som den blokken som falt ned.

Det var et stort hell i uhellet at ingen mennesker ble skadd. På et bruk, nr. 5, strøk samtlige hus med, på bruk nr. 2 strøk våningshuset med. Raset stoppet temmelig nær husene på bruk nr. 4. I tillegg til husene med innbo kom så verdien av den ødelagte jord, likesom gårdveien og telefonlinjen ble ødelagt. At ingen mennesker forulykket skyldtes at praktisk talt alle arbeidet i fri luft. Bare en kvinne var inne i et av de husene som strøk med, og hun kom seg ut. Noen kreaturer gikk i tjor og beitet. To av dem ble drept. Skaden ble i første hånd taksert til kr. 380 000,—.

Husene var blitt ødelagt på den måten at de undre delene var mer eller mindre knust. De øvre delene, med takene, så flere steder ut som om de hadde seilt fremover på skredet, og var stillet skjevt eller veltet over. Men det var forbausende hvor lite taksteinene var knust. Det var mange hele vindusrammer, til dels med hele ruter i.

Hele høsten og vinteren kom det stadig mindre ras fra Storfjellet, og dessuten forårsaket raset selvsagt forstyrrelser i de hydrologiske forhold, så jord og slam rett som det var ble skyllet nedover uren.

Når uren kunne gli ut slik som den gjorde, kom det selvsagt av at den lå på en så bratt fjellskråning. Men det kan vel også ha spilt en rolle at finmaterialet, jorden, mellom steinene var bløt og virket som smurning.

Det er ganske klart, både etter erfaringene fra dette raset og fra forholdene i Storstovo, at det kan komme flere liknende ras i fremtiden, enten samme sted eller ved siden av. Det kan derfor ikke bli tale om å la noen bo så nær fjellsiden. Både bruk nr. 5, som fikk alle sine hus ødelagt, og bruk nr. 2, som fikk noen ødelagt, må bygge opp igjen på andre steder. Men et tredje bruk, nr. 6, har også sine hus så utsatt at de ikke bør beboes, og det er heller ikke særlig tillokkende å bo på det fjerde bruk, der hvor raset stoppet like innpå husene.

Å rydde de ødelagte 45 mål jord igjen vil bli et slikt kjempearbeid at det ikke er å tenke på. Det var heller ikke hensiktsmessig å legge ny vei gjennom rasmassene. Når husene på fire bruk ble flyttet, kom den gamle veilinje ikke til å være så praktisk, og en ny gårdsvei ble anlagt.

Det spennende var om vannet kunne sige gjennom raset og følge det gamle bekkefaret. Det viste seg ved første alvorlige regnvær at rasmassene er praktisk talt tette. Det dannet seg en svær sjø bak raset, og denne sjøen strakte seg så langt nordover at kjellerne på et femte bruk, nr. 1, sto under vann. Dermed var det bare ett av de seks bruk som ikke ble berørt av katastrofen, bruk nr. 3, som ligger sydligst på terrassen.

Å sprenge et avløp gjennom raset langs det gamle bekkefaret kunne selvsagt la seg gjøre, selv om det ble kostbart. Men et slikt avløp, enten det skulle være en åpen kanal eller et nedgravd rør, ville i høy grad være utsatt for å bli beskadiget, tettet igjen av nye ras. Det skal ikke så store masser til for å stenge et slikt avløp, og så ville man ha vannet inn i kjelleren igjen, foruten at oversvømmelse ville skade årsveksten. Det ble da til at man bestemte seg for å grave en kanal sydover mot Moelven. Av økonomiske grunner tenkte man først ikke å tappe denne sjøen helt ut, idet det ville bli så uforholdsmessig dyrt å grave dypt nok til å få alt vann ut. Noen få mål jord fikk man heller ofre. Men det viste seg snart at dette resonnementet ikke holdt. Vannet fra denne sjøen seg ned i grusen, og bløtet opp den fine sanden i bunnen av terrassen. Det begynte å trenge frem vann flere steder i underkanten av terrassen, særlig langs Moelven. Og sanden kom selvsagt sammen med vannet. Det var tydelig at det brygget opp til utrasninger, og hvis dette fikk fortsette, ville store deler av terrassen stå i fare for å rase ut. Det var da ikke annet å gjøre enn å få en tappeledning fra det dypeste punkt av sjøen, stort nok dimensjonert til å hindre enhver oppsamling av vann bak raset. Hvis dette ikke ble gjort, måtte man se i øynene at hele terrassen kunne være farlig å bo på. En utrasning som demmet opp hovedelven i Modalen kunne dessuten medføre uberegnelig risiko for gårder og bosetning nedover dalen.

Raset i Modalen 14. august 1953 er det eneste eksempel jeg kjenner hvor en fjellblokk er falt ned i en ur og har satt i bevegelse en masse 12 ganger så stor som blokken. Men det er sannsynlig at vi, når vi er oppmerksom på forholdet, vil kunne finne vitnesbyrd om liknende ras, som det ikke finnes beretninger om. Kaptein SKAAR har således pekt på et sted lenger oppe i dalen, hvor noe liknende kan tenkes å ha foregått. Jeg siterer fra hans beskrivelse:

«Det er en del urd langs n.-sida av Modalen (hoveddalen). De fleste steder er den overgrodd av skog og ikke lett å få øye på, men Vaulurdi ved Farestveit er tydelig nok tross litt krattskog. Den er nær 300 m høy og 350 m bred ved foten. Det er stein fra det bratte fjellet Stortungsgavlen ovenfor som har lagt seg til ro der. Men det er ikke alle steinsprang som har stanset i urda. På sørsida av elva, i haugen mellom Kalsåsen og Farestveit ligger der i dagen et par steinblokker, store som middels hus, som tydeligvis ikke kan være kommet dit annet steds fra enn fra Stortungsgavlen. De har altså rullet tvers over dalen og det spørs om ikke hele haugen er dannet på denne måten».

Raset i Modalen og ettervirkningene av det hadde altså følgende fire faser:

1. En fjellblokk på 24 000 tonn falt ned i uren under.
2. Uren, som lå i ca. 30° vinkel, skred ut, og 300 000 tonn ble skjøvet frem på terrassen.
3. Den fremskjøvne massen demmet opp den bekken som drenerte terrassen, og det oppstod en stor sjø i regnvær.
4. Vann fra den oppdemte sjøen seg ned i de dypere deler av terrassen, og ble årsak til utglidninger langs kantene av terrassen.

Det vil si at vi her fikk presentert på ett brett de fleste av de midler naturen bruker for å skade bosetning. Noe liknende kan selvsagt komme til å hende andre steder.

Manuskript mottatt 26. april 1954.

UTVIKLINGEN AV APPARATUR FOR HYDROTERMALFORSKNING

AV

GUNNAR KULLERUD

(Mineralogisk-Geologisk Museum, Oslo)

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Abstract: The present paper is an extract of a talk given at the University of Oslo in February, 1954. It deals with the development of apparatus and techniques of hydrothermal research.

The rapid development of this research during the last seven years is due largely to outstanding efforts at the Geophysical Laboratory in Washington.

Innledning

Vann enten i fast-, veske- eller gassfase spiller en fremtredende rolle i nærsagt alle de geologiske prosesser som foregår på jordoverflaten og i den øvre del av jordskorpen. Vannet har i disse prosesser to vesentlig forskjellige funksjoner, nemlig 1) en mekanisk funksjon og 2) en kjemisk funksjon. Vi skal i det følgende beskjeftige oss med de prosesser som foregår i hydrotermal-området, altså over 100° C, og hvor H_2O har en kjemisk funksjon.

Enhver moderne geolog innser behovet for systematisk forskning som kan gi oss opplysninger om den virkning vannet har på silikat-likevekter og om fase-likevektsforholdene i systemer som inneholder både vann og silikater. Bare gjennom slik forskning kan man løse en rekke av de mest aktuelle problemer i forbindelse med magmatisk differensiasjon, pegmatitdannelse, og metamorfose samt konsentrasjon og avsetning av mineraler.

Ved en rekke forsknings-sentrer er det blitt innsett at hydrotermalundersøkelser er et nødvendig skritt fremover i anvendelsen av fysikalsk-kjemiske metoder på problemer innen geologien. Særlig siden 1948 er intensiteten øket innen denne gren av forskningen.

Det er nå ca. 100 år siden de første hydrotermalsynteser ble foretatt i laboratoriet. Hydrotermalsyntesens historie kan ikke skrives uten at navn som SCHAFHAÜTEL, WÖHLER, SÉNARMONT samt MASCHKE, DAUBRÉE, DEVILLE, FRIEDEL og SARASIN gis en fremtredende plass.

Mange «mineraler» er fremstillet ved hydrotermalsynteser — eksempler er kvarts, feltspat, wollastonit og analcit. En liste over alle «mineraler» fremstillet på denne måte ville allerede før år 1900 inneholde 80 forskjellige, definerte produkter.

De tidlige hydrotermalforskere var først og fremst interessert i å fremstille kunstige mineraler. De var imponert over at dette i det hele tatt kunne gjøres og var ikke interessert i å definere forholdene under hvilke syntesene fant sted. Systemene de arbeidet i var tilfeldig valgt og var ofte svært kompliserte, hvilket resulterte i at deres synteser ikke gav opplysninger som kunne lede til en løsning av noen av de fundamentale problemer i petrogenesen.

Den tid er forlengst forbi da syntese av et mineral under forhold som ikke har noe å gjøre med dets petrogenese, og ingen forbindelse med kjente likevekter, har noen interesse. Hva vi trenger er systematiske likevektsdata oppnådd under kontrollerte og reproduserbare forhold som iallfall i noen grad ligger nær hva man kan vente å finne i naturen.

Eldre typer av hydrotermalbomber.

Studier av hydrotermalprosesser består i å undersøke forholdene i visse vannholdige systemer både under og over vannets kritiske temperatur. De eksperimentelle vanskeligheter ved å undersøke vannholdige oppløsninger ved høye temperaturer og høye trykk er mange, men de fleste er forbundet med valget av passende apparatur og kontrollinstrumenter. De høye trykk som oppstår (ved oppvarming av rent vann eller vannholdige oppløsninger), samt vannets oppløsningsevne ved høye temperaturer utelukker en generell anvendelse av glass-apparatur. De fleste forskere anvendte bomber av stål. Dengang SÉNARMONT[1] begynte sine hydrotermalundersøkelser var kanonstål det beste materiale å oppdrive. Hans forsøk foregikk derfor i et tillukket kanon-løp. DOELTER[2] foretok likeledes en del av sine forsøk med lignende utstyr. Det er innlysende at med slik apparatur måtte der oppstå mange eksperimentelle usikkerheter. Små unøyaktigheter i tilpassingen av toppen eller bunnen av bombene tillot ofte endel eller undertiden all H_2O å unnslippe.

FRIEDEL og SARASIN [3,4] anvendte ved mange av sine forsøk en stålsylinder som var lukket i begge ender med lokk som blev holdt på plass av gjennomgående bolter. Mellom lokkene og sylinderen blev plasert kobberringer for å oppnå bedre tetning. DOELTER[5] anvendte en lignende anordning, men fant at den maksimale temperatur som kunne anvendes var 450° C. Kobberringene måtte skiftes ofte.

BAUR[6] anvendte en bombe som bestod av en stålsylinder. Sylinderen var boret ut fra den ene ende. Den øvre del av boringen var forsynt med gjenger og var litt større i diameter enn den nedre hvor forsøket foregikk. En kobberpakning ble anbrakt på skulderen mellom den større og mindre diameter. Efterat substans var anbrakt i forsøkskammeret og kobberpakningen satt på plass, ble en stålpropp, som var forsynt med gjenger til å passe den større hulldiameter, skrudd ned til anlegg mot kobberpakningen. Ved stramning av proppen mot pakningen kunne en viss forsetning oppnås. Såfremt flytegrensen ikke ble overskredet ville derfor bomben være tett til dampen utøvet et trykk lik forsetningen.

MOREY og FENNER[7] konstruerte senere en bombe som var tett selv med forholdsvis store trykk. Prinsippet anvendt i denne bombe blev siden adoptert av en rekke forskere. Bomben bestod av en sylinder av verktøystål. Hull blev boret omtrent som i BAUR's bombe, og den var utstyrt med den samme skulderanordning. På skulderen blev anbrakt en herdet kobberring. Istedenfor å la trykket fra en tilskrudd stålpropp virke direkte mot kobberringen blev MOREY's og FENNER's bombe også forsynt med en stempellignende anordning laget av verktøystål. Den ene side blev laget slik at den passet nøyaktig til den mindre hulldiameteren og den annen så den passet nøyaktig til den større diameteren. Når stemplet blev satt inn i bomben, blev

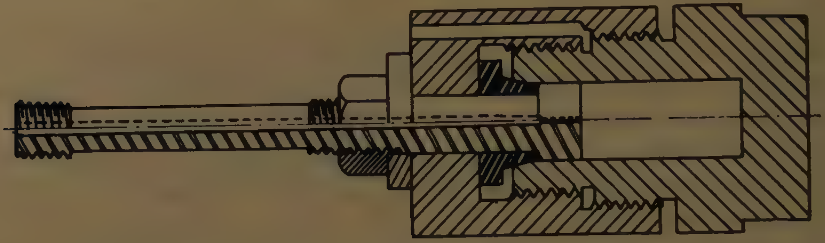

Fig. 1. Hydrotermalbombe med BRIDGMAN lukkemekanisme. (G. W. MOREY, Am. Ceram. Soc. bd. 36, s. 280, 1953.)

den herdede kobberring innelukket og flytning av kobberet kunne derved forhindres selv ved høye trykk og temperaturer. Det blev også funnet hensiktsmessig å anbringe en kobberskive oppå stemplet for å hindre skjærspenninger i kobberringen. Derved blev trykket fra tilsetningsproppen forplantet gjennom kobberskiven til stemplet. Den samme type lukkemekanisme blev anvendt i en bombe beskrevet av MOREY og INGERSON.[8] Denne arbeidet upåklagelig ved trykk opptil 1000 atm. og kunne tåle dobbelt så store trykk, men hadde den kjedelige feil at den ikke var tett under avkjølingen etter forsøkets slutt. Dette skyldtes forskjellen i den termale utvidelseskoefficient hos kobber og verktøystål. Bridgman konstruerte en lukkemekanisme som har vist seg fullstendig pålitelig. Denne bombe er vist i fig. 1. I dette spesielle tilfelle er der boret hull gjennom hele stemplet så bomben kan forbindes med et trykkreservoir. Stemplet holdes på plass av en pakning som igjen kan tilsettes ved hjelp av gjengene i lokket. Mellom stemplet og den nevnte pakning ligger en ringformet pakning laget av sølv eller kobber. For å oppnå at bomben er tett ved begynnelsen av et forsøk dras mutteren på toppen av bomben litt til så pakningen klemmes mot veggen av bomben og mot stemplet. Tetthet ved økende trykk i bomben besørges av trykket selv. Stempelhodet presses mot den tynne ringformete sølv- eller kobberpakning som forsegler bomben. Trykket virker på hele stempelhodets flate som er mange ganger større enn ringens, derved blir trykket i kg/cm_2 mange ganger større på ringen enn på stemplet. Denne lukkemekanisme har vært anvendt i lengere tid og er effektiv ved trykk opptil 2000 atm ved 600° C. Den er brukbar for langtidsforsøk ved 3000 atm. hvis temperaturen ikke overstiger 500° C. Oftest har det til denne type bomber vært anvendt et rustfritt stål for selve bomben, samt for stemplet og for den store pakningen, mens toppen av bomben har vært laget av et molybdenstål. Der har vært brukt et grafitsmøremiddel for gjengene. Dette smøremiddel bevirker at molybdenstålet herdes, mens dette ikke skjer med rustfritt stål. Det er derfor fare for skjæring i flatene hvor rustfritt stål ligger an mot rustfritt stål. Ikke en gang et smøremiddel som molybdensulfid kan gi effektiv beskyttelse mot slike angrep. Vedvarende oppvarming ved 500° C eller gjentatte 24 timers forsøk ved 600° C vil gradvis forårsake deformasjon av rustfritt stål. Forskjellige legeringer har vært anvendt. Inconel X er best skikket under ekstreme trykk- og temperaturforhold, men også dette må bite i gresset for den korroderende virksomhet hos sterkt alkaliske gasser.

Et interessant fremskritt i utviklingen av hydrotermalapparaturen blev gjort av KÖNIGSBERGER og MÜLLER[9] som satte et platinafilter inn i sine bomber. Derved kunne faste stoffer skilles fra veskefasen ved enhver temperatur. Dette filter fant dog ingen stor anvendelse. Andre forskere, som vanligvis arbeidet ved lave trykk og tempraturer, laget andre apparaturer for å skille de faste stoffer fra veskefasen. WALDECK, LYNN og HOLL[10,11], var med en slik apparatur istand til å måle oppløseligheten av natrium-karbonat i vann opptil 348° C. Lignende arbeider med samme type apparatur er siden utført av SCHROEDER og medarbeidere[12,13], og av STRAUB[14], HITCHEN[15] og NORTON[16].

Hydrotermalarbeider blev vanligvis utført i lukkede bomber. Vann blev fylt i bombene sammen med fast substans. Trykket utviklet i bomben blev beregnet fra forsøkstemperaturen og fyllingsgraden av bomben, (det vil si tettheten beregnet utfra vannmengden i bomben dividert med bombevolumet). De nye forsøk foretatt av KENNEDY[17] av trykk-volum-temperatur forholdene hos vann ved høye trykk og temperaturer har fjernet noen av usikkerhetsmomentene ved ovennevnte type beregninger i de tilfelle hvor bare gass og fast substans er til stede. Når en veske er tilstede samtidig, er der selvsagt ingen relasjon mellom det sådan beregnede trykk og det virkelige trykk som vil være veskefasens damptrykk. Trykket vil bli bestemt av oppløsningens karakter. Anvendes en substans som er lettløselig vil det virkelige trykket være meget mindre enn det som kan beregnes fra fyllingsgraden, hvis temperaturen er høyere enn vannets kritiske temperatur. I området under vannets kritiske temperatur vil det virkelige trykket være meget mindre enn damptrykket over rent vann.

Ved Geophysical Laboratory i Washington ble der i 1941 uteksperimentert en ny metode for kontroll av fyllingsgrad og trykk i hydrotermalbomber[18]. Vann pumpes gjennom en høytrykksledning først til et reservoir som sørger for trykkutjevning i systemet og derfra til en bombe med Bridgman-typen lukkemekanisme. Trykket under forsøkene er derved en direkte kontrollert variabel. Både trykket og temperaturen i bomben kan holdes konstant. Vanninnholdet i bomben blir derfor en avhengig variabel. Den vannmengde som kommer inn i bomben ved konstant temperatur og volum bestemmes av trykket. Når veskefase ikke er tilstede er mengden bestemt av trykk-volum-temperatur forholdet hos H_2O med den korreksjon som kan skyldes substans i gassformig oppløsning. Når veskefase er tilstede må vanninnholdet i denne fase være slik at vanndamptrykket er lik det trykk som vannet har i trykkledningen.

Morey og Hesselgesser[19,20] har, ved å anvende en noe modifisert type av ovennevnte apparatur vært i stand til å undersøke oppløseligheten av en rekke mineraler i overhetet vanndamp. Interessante er resultatene av bestemmelsene av oppløseligheten av kvarts i overhetet vanndamp. Ved ca. 2000 atm. og 600° C er oppløseligheten 0.77 vektsprosent. Denne oppløselighet er stor nok til å forklare dannelsen av kvartsårer og til å være ansvarlig for kvarts på pegmatitganger. Disse forsøkene gjorde det klart at kvarts ved høye temperaturer er lettere oppløselig i overhetet vanndamp enn noe annet oksyd som man har hatt anledning til å undersøke de tilsvarende forhold hos. Det er i virkeligheten ikke overraskende at en gass kan opptre som oppløsningsmiddel for faste substanser. Vanndamp ved 2000 atm. og 400° C har en tetthet på 0.79, ved 500° C er tettheten 0.69 og ved 600° C er tettheten 0.60. Tettheten av vanndamp ved 2000 atm. er derfor ikke vesentlig forskjellig fra vannets ved romtemperatur.

Denne oppløselighet av silika forklarer den sannsynlige mekanismen ved hydrotermalreaksjoner hvori silika inngår og hvor veskefase mangler.

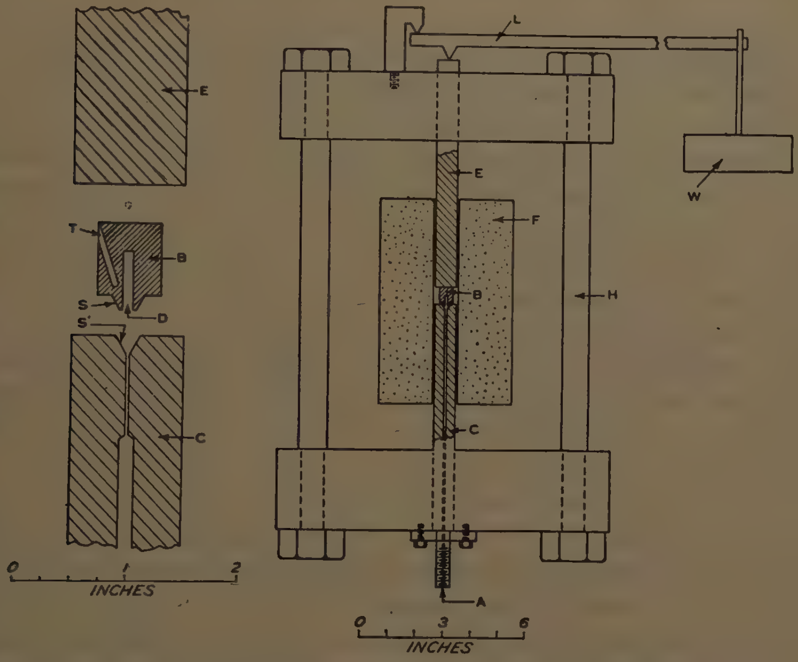

Fig. 2. Hydrotermalapparatur konstruert av TUTTLE. (O. F. TUTTLE, Am. Jour. Sci. bd. 246, s. 629, 1948).

Tuttle-apparaturen.

TUTTLE[11] konstruerte i 1948 en apparatur spesielt skikket for undersøkelser hvor veskefase ikke er tilstede og hvor derfor reaksjonen foregår mellom gassfasen og den faste fase. Konstruksjonen av apparaturen er vist i figur 2.

Bomben (B) sitter på stålstangen (C) og forseglingen besørges av et nedadrettet trykk på stålstangen (E). Dette trykket frembringes ved hjelp av vektstangen (L) og vekten (W). Det konstante trykket som utøves av vekt og vektstang sørger for at lekasje i bomben ikke oppstår selv om denne til en viss grad deformeres som følge av høye trykk og temperaturer. Under forsøk har det forekommet at bomben er blitt sammentrykket ca. 10 % i vertikalretningen uten at derved lekasje har oppstått. Bomben er konisk i den ene ende som vist i figur 2. Vinkelen er 59°. Den koniske del av bomben passer inn i understykket som har et 60° konisk sete. Den lille forskjell på 1° i konitet sørger for at lukkemekanismen er effektiv. Ideen er forsåvidt av eldre dato da den i endel år har vært anvendt for forbindelser mellom høytrykksstålrør i industrien. Vann innføres i systemet gjennom et aksialt hull av svært liten diameter gjennom den sylinderformete stav C. Enden av denne (ved A) er forbundet med en trykkledning av rustfritt stål. Forbindelsen her er av samme type som ovenfor nevnt med et konisk sete, men tetningen besørges av en mutter. Trykkledningen er forbundet med en trykkutjevningssylinder som har et volum på 2500 cm^3. Dette er et tilstrekkelig stort volum til å utjevne små trykksvingninger i systemet. Denne sylinder er igjen forbundet med en pumpe som leverer vann av ønsket trykk (opptil 3000 atm.).

De koniske flater på bombe og sete korroderes litt under hvert forsøk; derfor bør flatene pusses litt med et meget finkornig mergelpapir efter hvert eksperiment. Hvis deformasjon har funnet sted må dette rettes på ved dreining.

På grunn av at mange oppløsninger reagerer med stålet i bomben var det vanlig at de fleste forskere foret iallfall de lukkede bomber med mere motstandsdyktige metaller som sølv, gull eller platina. BAUR[6] fremholdt at dette ikke var nødvendig fordi det ville dannes et jernoxydskikt på bombeveggene. Dette ville så beskytte mot videre korrosjon. Det er utvilsomt riktig at nøytrale oppløsninger vil vise liten evne til å reagere med stålet, men når sure eller sterkt alkaliske oppløsninger opptrer, kan den oppløsende evne på stålet ikke lenger oversees. De oppnådde produkter fra slike forsøk er ofte forurenset med jern. Jernet korroderes undertiden så meget at hele mineral-assosiasjonen kan forandres. Det er nå en alminnelig utbredt mening blant hydrotermalforskere at å fore bombene med et edelt metall ikke er påkrevet, men det anses nødvendig å anbringe den faste substans i en beholder laget av gull eller platina. Erfaringene under sådanne forhold har vist at tiltross for at en lukket bombe ofte angripes kraftig av oppløsningene, så viser innholdet av edelmetallbeholderen sjelden tegn på forurensninger av nevneverdig betydning.

Det er vanlig praksis ved forsøk med Tuttle-apparaturen å anbringe den faste substans i en platinakonvolutt som så settes inn i bomben. Bombevolumet er i sammenligning med vanlige lukkede hydrotermalbomber svært lite. Hulldiameteren er ca. 3 mm og dybden ca. 11 mm. Volumet er derfor ca. 75 mm^3. Når man tar bort det volum som platinakonvolutten krever, kan man ikke regne med å operere med mere enn 40 mgr substans i hvert forsøk. For senere undersøkelser ved hjelp av mikroskop og røntgenstråler er dette imidlertid mere enn nok.

Bomben, samt deler av de sylinderformede staver over og under denne oppvarmes ved hjelp av en delt ovn. Denne er vertikal og dens to halvdeler kan svinges uavhengig av hverandre om en vertikalakse ved hjelp av hengsler. Temperaturen måles ved hjelp av et termoelement som settes ned i et hull i bomben. Ved temperaturer opptil 600° C anvendes gjerne et jern-konstantan termoelement og over denne temperatur anvendes et chromel-alumel termoelement. Sveisepunktet på termoelementet befinner seg ca. 3 mm fra platinakonvoluttens midtparti. Temperaturgradienten over denne avstand er ukjent, men som et holdepunkt kan nevnes at den vertikale temperaturgradient i bombens lengde er mindre enn 1° C pr. cm. Det er derfor grunn til å anta at forskjellen mellom den avleste temperatur og temperaturen i bomben ikke overstiger 5° C. Temperaturen reguleres ved å anvende elektrisitet av stabilisert spenning i forbindelse med en Variac. En Brown «temperature recorder» bør fortrinsvis anvendes for kontinuerlig temperaturavlesning.

Bourdon-typen manometere er i TUTTLE's opprinnelige apparatur anvendt til måling av trykket. Disse trykkavlesninger bør ikke tillegges større nøyaktighet enn ± 10 %.

Det er en sjeldenhet at man kan oppnå et fullstendig lekasjefritt system, derfor er det anbefalingsverdig å utstyre apparaturen med en automatisk trykkregulator. En justerbar ekstra viser på manometeret innstilles ved et trykk bestemt av hvor høyt trykk man ønsker under vedkommende forsøk. Efter at et eksperiment er startet og trykket begynner å synke som resultat av lekasje i systemet vil trykkviseren snart berøre den justerbare viser. Derved sluttes en strømkrets som gjennom et thyratronrør innvirker på et relée som setter igang den elektrisk drevne pumpen. Pumpen stanser igjen når det ønskete trykk igjen registreres på manometeret.

En av grunnene til at bomben er såpass liten er at den derved

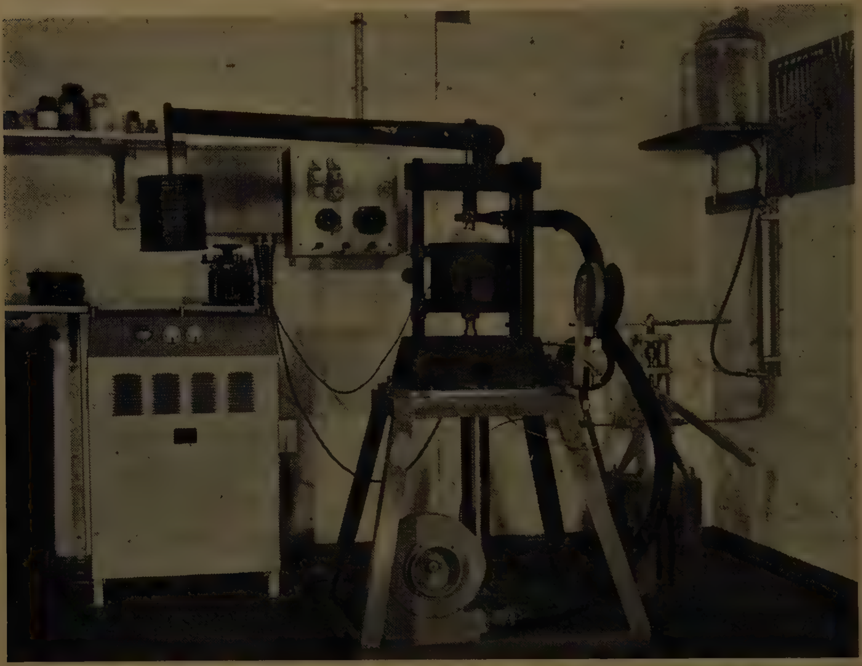

Fig. 3. Hydrotermalapparatur anvendt ved Mineralogisk-Geologisk Museum, Oslo.

kan avkjøles hurtig. Dette er selvsagt viktig for å kunne fryse likevekter oppnådd ved forsøkstemperaturen. Ved forsøkets slutt svinges ovnen raskt tilside. Bomben kjøles med blåseluft. En vifte blåser en kraftig luftstrøm gjennom en slange og derfra gjennom et ringformet metallrør med mange små hull rettet radialt mot ringens sentrum. Ringen omgir den øvre sylindriske stav og kan senkes til bombens høyde. I denne kjøleluften kan bombetemperaturen senkes meget hurtig. TUTTLE oppnådde 300° temperatursynking i løpet av 10 sekunder.

Hydrotermalapparatur i det vesentlige lik den TUTTLE konstruerte har i det siste året vært i bruk ved Silikatforskningslaboratoriet ved Mineralogisk-Geologisk Museum, Oslo. Denne apparatur er vist i figur 3. Lengst til høyre, på en hylle oppe på veggen, står en flaske fylt med destillert vann. Vannet ledes ned i en mindre beholder laget av rustfritt stål. Forbindelsen er åpen mellom denne og trykkpumpen som er laget av det engelske firma Weir Precision Engineering Ltd. Pumpen er manuell, dens slagvolum er ca. 1 cm³ og den er konstruert for å kunne arbeide ved trykk på opptil 2 000 atm. Fra pumpen trykkes vannet inn i trykkutjevningssylinderen. Denne er laget av Stavanger-stål som blev herdet etter den maskinelle bearbeidelse. Hulrommet i sylinderen er ca. 2500 cm³. Høytrykksledninger forbinder pumpen og sylinderen. Disse er laget av American Instrument Co. og består av rustfritt stål. Utvendig diameter er ca. 7 mm. Det utborede tverrsnitt er ca. 1 mm². Alle forbindelser mellom trykkledning og den øvrige apparatur skjer ved koniske seter av type omtalt tidligere. Mellom sylinderen og pumpen er anbragt et manometer av typen Dura-gauge. Dette er anvendbart opptil 3000 atm. og er funnet å arbeide meget tilfredsstillende. Trykkledningen fra pumpen er forbundet med den nedre ende av den vertikaltstående trykkutjevningssylinder. Trykkledningen som fører fra denne til bomben er forbundet med sylinderens topp for å hindre akkumulering av luft i sylinderen. Mellom sylinderen og bomben er der først anbrakt tre nålventiler i rekke og rad. Derefter er innsatt på trykkledningen et manometer av samme type som det før nevnte. Dette siste er anbrakt for avlesning av trykket i bomben og som en kontroll på det første manometer. Den første av de nevnte nåleventiler tillater avstengning av utjevningssylinder og pumpe fra det øvrige system. Dette er praktisk fordi man efterat et forsøk er over kan vedlikeholde trykket i utjevningssylinderen, mens man tar av bomben og gjør klart for neste forsøk. Man spares derfor for en del manuell pumping. Den neste ventil tillater at man slipper eventuell luft ut av systemet. Dessuten er det gjennom denne ventil mulig å forlenge trykkledningen til parallelt arbeidende hydrotermalapparaturer som derved kan mates fra samme pumpe og samme trykkutjevningssylinder. Den tredje ventil gjør det mulig å avstenge bomben fra resten av systemet. Dette er nødvendig hvis man har flere hydrotermalanlegg i virksomhet under forskjellige trykk. Ventilene er av rustfritt stål og leveres av American Instrument Company.

Materialet i de sylindriske staver under og over bomben er rustfritt stål. Selve bomben kan lages av Hastelloy C eller Falloy 11.

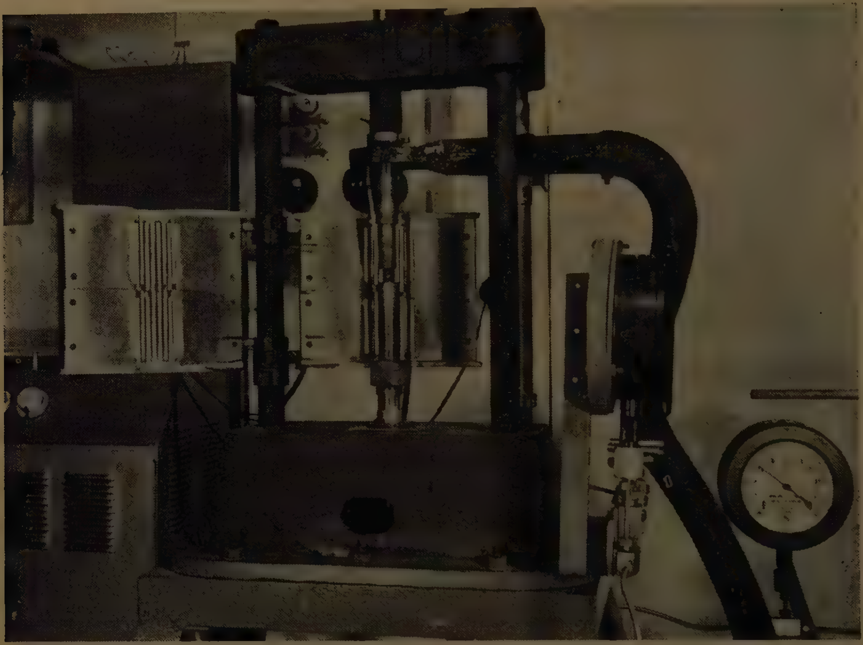

Fig. 4. Samme apparatur som vist i figur 3 efterat ovnen er svinget til side så bombeanordning er synlig.

For høyere trykk og temperaturer bør anvendes Nimonic-alloy og for ekstreme forsøksbetingelser Stellit.

Den delte nichrome-viklede vertikalovn tilføres energi gjennom en Variac som mottar elektrisitet av spenning 220 volt ± ½ % fra en ASEA spenningsstabilisator. Ovnen er på 800 watt ved full spenning. I figur 4 er vist bomben og de sylindriske staver når ovnen er svinget tilside. Avkjølingsmekanismen ses til høyre.

Denne apparatur arbeider upåklagelig ved trykk opptil 1500 atm. ved en temperatur på 600° C. Systemet er praktisk talt fri for lekasjer. Under et forsøk er det bare nødvendig å justere trykket i løpet av den første dagen, derefter synker ikke trykket. Enkelte forsøk har gått i 30 dager eller mer ved 1500 atm. og ved temperaturer opptil 550—600° C uten at trykkregulering har vært nødvendig, bortsett fra den første dagen.

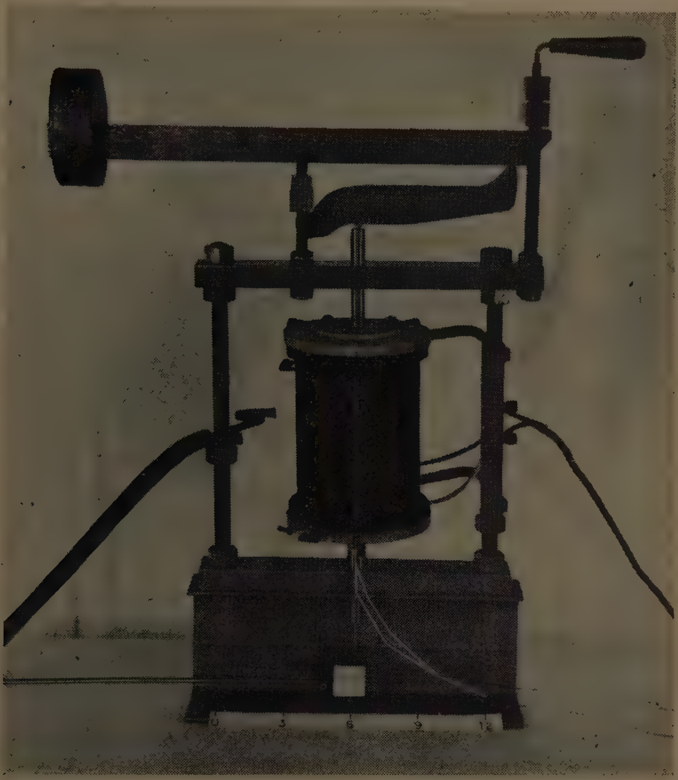

Fig. 5. Yoder og Van den Heurk's konstruksjon for hydrotermalapparatur. Denne er i bruk ved Geophysical Laboratory og er i det vesentligste en betraktelig forbedret versjon av den opprinnelige Tuttle-apparatur. (Målestokk angir tommer).

Apparaturen har imidlertid sine ulemper. Den tar for eks. forholdsvis stor plass i laboratoriet, og videre kan bare ett forsøk kjøres om gangen. Særlig i ternære systemer, hvor H_2O er den ene komponent opptrer ofte metastabile faser. Ved å bare kunne kjøre et forsøk om gangen kan det ofte ta lang tid før stabile faser oppnås ved et gitt trykk og en gitt temperatur. Hydrotermalundersøkelser med Tuttle-apparaturen ved Mineralogisk-Geologisk Museum i systemet CaO-SiO_2-H_2O har demonstrert tydelig nok vanskelighetene ved å utarbeide ternære systemer ved hjelp av én-bombe-apparatur.

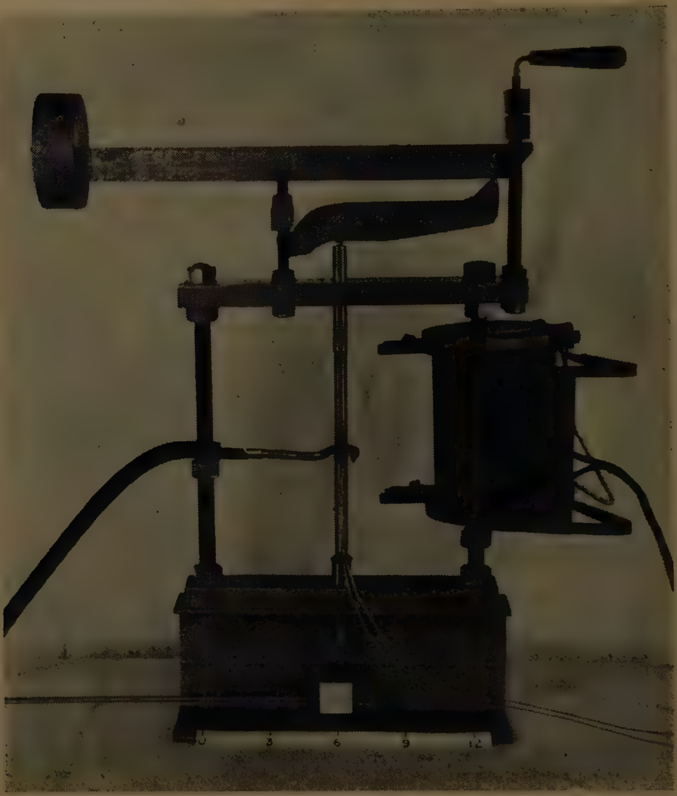

Fig. 6. Samme apparatur som vist i figur 5 efterat ovnen er svinget til side så bombeanordning og avkjølingsmekanisme er synlig. (Målestokk angir tommer).

Forbedringer av Tuttle-apparaturen.

Yoder og Van den Heurk[11] ved Geophysical Laboratory i Washington forbedret Tuttle-apparaturen betraktelig. Figur 5 viser resultatet av deres bestrebelser. Pumpen og trykkutjevningssylinderen er ikke tatt med her. Denne apparatur krever langt mindre plass enn Tuttle-apparaturen. Den største bredde er ca. 60 cm. Ved å anvende en dobbel vektstang spares laboratorieplass samtidig som mindre motvekt behøves. Apparaturen er montert på et kommersielt stålprofil som er satt opp på en benk. Derved innspares omkostnin-

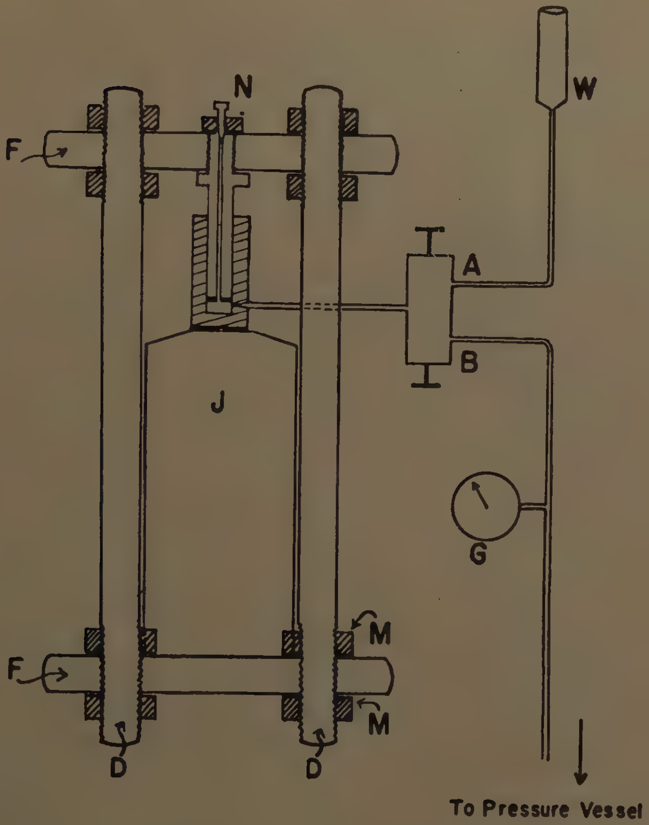

Fig. 7. Skjematisk oversikt over ROY's konstruksjon for hydrotermalapparatur anvendt ved Pennsylvania State University. (R. ROY, E. F. OSBORN., Econ. Geol. bd. 47, s. 719, 1952.)

gene ved stativet som vi så Tuttle-apparaturen var forsynt med. Trykkledningen kommer inn fra venstre på figuren. Den kan med letthet forlenges på den annen side av koblingspunktet og således føre til en rekke apparaturer av samme slag. YODER mater således 10 apparaturer fra én pumpe og én trykkutjevningssylinder. Det er praktisk å koble inn en nålventil og et manometer for hver apparatur for å kunne stenge apparaturen av fra systemet når det riktige trykk for de individuelle forsøk er oppnådd. Luftslangen settes på vertikalstaven, som vist, med en klype. Når man sørger for at slangen er lang nok, kan den betjene alle apparaturer. I figur 6 er ovnen svinget til side. Det er her vist hvordan bomben avkjøles med luft som blåses ut av en rekke radialt rettede hull i det halvsirkelformede metallrør på enden av luftslangen.

RUSTOM ROY[23] ved Pennsylvania State University har gått et lite skritt videre i forenklingen av hydrotermalapparaturen. Hans apparatur er vist skjematisk i figur 7 og skal bare omtales ganske kort. Komprimering av vann skjer ved hjelp av et stempel som er nøyaktig tilpasset et sylinderformet hull i en sylindrisk blokk av rustfritt stål. Under trykk-kammeret er plasert en 20 tonns «jack». Denne, såvelsom den øvre ende av stemplet er spent fast i en stålramme slik at når «jack'en» skrues opp, trykkes stemplet som også er av rustfritt stål, ned i trykk-kammeret. Nær bunnen av kammeret er der boret et hull i sylindersiden. Her er en trykkledning tilkoblet ved hjelp av koniske seter. Trykkledningen leder til en dobbelt ventil. Den ene side står i forbindelse med et reservoir av destillert vann og gjennom den andre tilføres hydrotermalapparaturene vann av ønsket trykk. Ved senkning av «jack'en» trekkes stemplet oppover i trykk-kammeret, eller rettere sagt kammeret trekkes nedover. Ved å åpne ventilen til vannreservoiret kan så kammeret fylles med destillert vann. Det vil si litt luft blir innestengt oppunder stempelbunnen. For å få denne luften ut er der boret et aksialt hull gjennom stemplet. På toppen av dette sitter en liten nålventil. Ventilen til vannreservoiret lukkes og ventilen i stemplet åpnes. Når så «jack'en» heves, drives luften ut. Ventilen i stemplet lukkes når vann begynner å sive ut. Ved fortsatt hevning av «jack'en» bygges der opp et stort vanntrykk i kammeret. Kammerets volum er på ca. 5000 cm^3.

Denne enkle apparatur som tjener både som pumpe og trykkutjevningssylinder kan mate 20 hydrotermalbomber med vann av opptil 3000 atm. Hver av disse 20 hydrotermal-apparaturene grener seg ut fra høytrykkshovedledningen og er utstyrt med egne manometere og ventiler som kan stenge dem av fra resten av systemet. Ved å holde et høyere trykk i kammeret enn krevet i bombene kan man variere trykket fra bombe til bombe etter ønske. Ovnene som anvendes er ikke delte som de før omtalte. Istedenfor å svinges til siden kan de heves eller senkes ved hjelp av stålwire og trinser. Lodder på enden av wirene balanserer ovnene i enhver høyde. Disse udelte sylinderformede ovner er enklere og billigere enn de delte og utmerker seg også ved mindre varmetap.

Avsluttende bemerkninger.

Utviklingen av apparaturen for hydrotermalforskning er kommet så langt at vi kan efterligne endel av de prosesser som foregår eller har foregått i jordskorpen og hvor vann har deltatt.

Likevektsforholdene i en rekke vannholdige silikatsystemer og stabilitetsforholdene for en rekke mineraler er undersøkt med hydrotermalapparaturer av de 3 nevnte typer. Vi skal imidlertid huske på at laboratorieforsøkene foregår under statiske forhold og at den faste fase og gassfasen er utsatt for et og samme trykk.

Mange prosesser i jordskorpen foregår under forhold forskjellig fra disse. I mange tilfelle forekommer mekanisk deformasjon under hydrotermalprosessene. Det er nok heller ikke uvanlig at bergartene er utsatt for høyere trykk enn de perkulerende oppløsninger eller gasser. I første tilfelle vil, ved de rette temperaturer, prosesser som spaltning av andalusit, sillimannit eller kyanit til kaolin — eller spaltning av spinel til korund og brucit kunne skje. I det annet tilfelle vil oppløselighetsforholdene forandres totalt og mange mineraler som vi til dags dato ikke har klart å syntetisere er kanskje dannet på en slik måte.

Den videre utvikling av hydrotermalapparaturen pågår. Rustum Roy er for tiden sterkt opptatt med å konstruere apparatur hvori den faste substans kan deformeres mekanisk (f. eks. ved maling) under hydrotermalbetingelser. Arbeide pågår likeledes for å overvinne de tekniske vanskeligheter ved konstruksjonen av et hydrotermalanlegg hvor den faste substans kan utsettes for et trykk forskjellig fra det som påvirker gass eller veskefasen. Apparaturutviklingen gjør oss stadig bedre og bedre istand til å efterligne de forskjellige prosesser som finner sted i jordskorpen. Gradvis kommer vi nærmere vårt mål, nemlig å forstå den fysikalsk-kjemiske reaksjonsmekanismen i jordskorpen og å kunne anvende vår viten til å løse geologiske problemer.

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Manuskriptet mottatt 26. september 1954.

NY LITTERATUR

KALERVO RANKAMA: «*Isotope Geology*». 24.7 cm × 16.7 cm, XVI + 536 sider, 37 figurer og 4 plancher, pris 75 s. Pergamon Press Ltd., London 1954.

Isotop-geologien er en ny gren av videnskapen som for første gang bevisst presenterer seg selv som et selvstendig forskningsområde ved utgivelsen av Rankamas mektige bok.

Isotop-geologien er studiet av geologiske fenomener ved hjelp av de stabile og ustabile element-isotoper og deres mengdefordeling i mineraler og bergarter.

De radioaktive nuclider (eller isotoper) har helt siden radioaktivitetens barndom vært anvendt på geologiske problemer. Dette har vært kalt radiogeologi; og ved samarbeide mellom kjernefysik- kjemi og geologi var man kommet frem til interessante resultater angående jordens varme-balanse, historie, struktur, og kjemiske sammensetning.

Men lenge hersket blandt kjemikere og geologer den antagelse at, frasett de radioaktive elementer og deres spaltningsprodukter, var hver især av de stabile elementer oppbygget av isotoper i et ganske bestemt mengdeforhold der var å betrakte som en naturkonstant; følgelig var atomvekten av et element alltid den samme uansett det geologiske milieu som elementet befant seg i.

Men denne antagelse måtte falle for de nye forskningsresultater som er kommet i løpet av de siste par decennier. Direkte analyser har vist til dels store variasjoner i isotopsammensetningen hos ett og samme element fra forskjellige naturlige finnesteder. Teoretiske overlegninger har forklart dette faktum: de kjemiske egenskaper hos de forskjellige isotoper av et gitt element er ikke identiske; egenskaper av betydning for de kjemiske reaksjoners kinetik er også forskjellige, og har vært brukt til å beregne størrelsen av en naturlig isotopfraksjonering. De seneste års arbeider viser klart at de naturlige variasjoner i isotop-sammensetningen hos elementene er meget større enn man før trodde mulig; man må anta at de eksisterer selv langt oppe i det periodiske system. Isotop-geologien er i dag i stadig vekst og i sterk ekspansjon. Den har hittil for det meste vært drevet av fysikere og kjemikere. Rankamas bok vil sikkert få geologene til å forstå hvilke store muligheter der byr seg ved å anvende isotopstudier på en rekke geologiske problemer.

Boken er delt i to dele. Part I gir for den geologiske leser en oversikt både over nuclidenes fysikk og kjemi, og over de viktigste metoder innenfor isotop-geologien. Part II behandler nuclidenes naturvidenskap, d. e. den måte de opptrer på i naturen. Den gir en samling av data så stor og fyldig at man imponeres. Den gir også et forsøk på å forklare disse data. Arbeidet med innsamlingen og behandlingen må ha vært så stort at man skulle tro et institut med en stab av medarbeidere måtte stå bak, og ikke en enkelt mann. Litteratur-referancene overskrider 1200. Registeret opptar 55 sider med tett petit trykk. Ikke på noget sprog var en bok blitt skrevet som dekker isotop-geologens store felt. Alle opplysninger var vidt spredte i videnskapelige tidsskrifter for fysikk, kjemi, astronomi, geologi, oceanografi, biologi og arkeologi. Det er all grunn til å graturere profesor Rankama med fullførelsen av et stort og betydningsfullt verk.

Følgende sterkt forkortede innholdsfortegnelse gir en nærmere oversikt over en del av stoffet i boken:

Part I: Physics and Chemistry of Nuclides.

Atoms, Nuclei and Nuclides. — Structure of the atom; mass and energy; elementary particles of matter; distribution of orbital electrons; structure of the nucleus; proton, neutron and mass number; nuclides; properties of the nucleus; charts of nuclides; existence and abundance of nuclides; occurrence of nuclides in Nature.

The Periodic System — Isotopy. — Discovery of isotopes; isotopic moment and separability of isotopes; theory of isotope fractionation; separation of isotopes.

Mass Analysis. — Spectro-isotopic analysis; analysis of mass spectra; determination of isotopic abundance ratios; applications of mass analysis; neutron-activation analysis.

Radioactivity. — Determination of half-life; branched disintegration; radioactive nuclides; natural radioactivity; artificial radioactivity; stability of nuclides against radioactive decay; units of radioactivity; measurements of radioactivity.

Properties of Nuclear Radiations. — Alpha-radiation; beta-radiation; gamma-radiation; neutrons.

Nuclear Reactions in Nature. — General remarks; the (α, n), (α, p), (γ, n), (η, n), (n, p), (n, γ), and $(n, 2n)$ reactions; natural fission, production of nuclides by cosmic radiation; occurrence of fission products derived from atomic explosions.

Geological Applications of Radioactivity. — Distributon of radioactivity in igneous rocks; radioactivity in geochronometry; age of the Earth; age of the elements; radiogenic heat in rocks; autoradiography; radioactive disturbances in mineral structures; age and rate

of deposition of ocean sediments; radioactivity and mineral deposits; radioactivity and the genesis of petroleum; radioactivity as an aid in concentration of ores; well logging by radioactivity; radionuclides in laboratory geology.

Abundance and Origin of Elements and Nuclides. — Terrestrial abundance of elements; cosmic abundance of elements; cosmic abundance of nuclides; origin of elements.

General Possibilities of Isotope Fractionation in Nature. — Natural separation mechanisms; time effect and age effect.

Part II: Natural Science of the Nuclides.

(I dette avsnitt behandles tilsammen 81 elementer; i det følgende gis eksempler for bare 6 av elementene).

Hydrogen. — Hydrogen isotopes; cosmic occurrence of protium and deuterium; protium and deuterium in meteorites; protium and deuterium in the atmosphere; protium and deuterium in the hydrophere; protium and deuterium in the lithosphere; protium and deuterium in the biosphere; tritium.

Carbon. — Carbon isotopes; cosmic occurrence of 12C and 13C; The carbon-nitrogen cycle; the isotopes 12C and 13C in meteorites; the isotopes 12C and 13C in the atmosphere, in the hydrosphere, in the lithosphere, in the biosphere; cycle of the isotopes 12C and 13C; original isotopic constitution of terrestrial carbon; the isotope 14C in Nature, the radiocarbon method for the measurements of age of cabonaceous material; geological applications of the method; archeological and anthropological applications of the method.

Oxygen. — Oxygen isotopes; cosmic occurrence of oxygen isotopes; oxygen isotopes in meteorites; oxygen isotopes in the atmosphere, the hydrosphere, the lithosphere, and in the biosphere; primordial isotopic constitution of terrestrial oxygen; cycle of oxygen isotopes; the oxygen method for the measurement of temperature.

Potassium. — Potassium isotopes; radioactivity of 40K; geological significance of the radioactivity of 40K; rate of production of radiogenic heat in the decay of 40K; the isotope 40K in Nature; the potassium method for the measurement of differential astronomical age; the isotopes 39K and 41K in Nature.

Uranium. — Uranium isotopes; fission of uranium; the uranium-isotope method for the measurement of age of radioactive minerals; the uranium-isotope method for the measurement of absolute and differential astronomical age; rate of production of radiogenic heat in the decay of uranium.

Plutonium. — Plutonium isotopes; plutonium isotopes in Nature.

Appendix 1. Numerical constants and conversion factors.

Appendix 2. International atomic weights for 1953.

Bibliography. Name Index. Subject index.

Tom. F. W. Barth.

NORSK GEOLOGISK FORENING

Generalforsamling torsdag 25. februar 1954.

Tilstede 21 medlemmer og 2 gjester.

Årsmelding for 1953.

Siden siste generalforsamling er foreningens medlem direktør Worm Hirsch Lund avgått ved døden.

4 medlemmer er utmeldt av foreningen.

I samme tidsrom er innvalgt følgende 16 nye medlemmer:

362 Kirsten Jakhelln
363 Bjørn Andersen
364 Henry V. Horve
365 Grover E. Murray
366 Kenneth E. Caster
367 Edmund Nosow
368 Oskar Kulling
369 Anker Iversen
370 Ørnulf Logn
371 Konrad B. Krauskopf
372 Olof H. Ødman
373 Anders Sahlin
374 Sverre Svinndal
375 Sigurd Holmberg
376 Brian H. Mason
377 Just Gjessing

Foreningen har nå 217 medlemmer, herav 2 korresponderende medlemmer, 104 livsvarige og 111 årsbetalende medlemmer. Det er avholdt 6 ordinære møter med samlet fremmøte av 229 personer og et ekstraordinært møte sammen med Geografisk Assosiasjon.

Av Norsk Geologisk Tidsskrift er bind 31, 32 og 33 h.1—2 utkommet.

Årsmeldinger fra Bergens og Trondheims Geologiske Klubber ble referert.

Utdrag av regnskap for det ordinære budsjett for 1953.

Inntekt:

Beholdning, overf. fra 1952:		
I kasse	kr. 261,38	
I bank	- 13 816,38	kr. 14 077,76
Innbetalt medlemskontingent		- 1 965,00
Tilskudd fra staten		- 1 200,00
—»— Norges Almenvitenskapelige Forskningsr.		- 25 000,00
Abonnement og salg av tidsskriftet		- 3 097,50
Renter av bankinnskudd		- 106,19
- og inntekter fra Livsvarige medlemmers fond		- 1 386,92
- av Berg- og Stenindustriens gavefond		- 390,04
Overført fra Berg- og Stenindustriens gavefond til ordinære budsjett		- 5 554,00
		kr. 52 777,41

Utgift:

Tidsskriftet:		
Trykking, bind 29 (særtrykk)	kr. 30,00	
— 30 h.1-4	- 10 821,63	
— 31 h.1-4	- 11 881,00	
— 32 h.1-4	- 11 167,00	kr. 33 899,63
Klisjeer, bind 30	kr. 2 204,88	
— 31	- 2 560,00	
— 32	- 1 960,00	- 6 724,88
Ekspedisjon av tidsskriftet		- 901,15
Arbeidshjelp, porto og skrivesaker		- 661,00
Møter og ekskursjoner		- 882,75
Rabatt ved salg av tidsskriftet		- 787,16
Anskaffelser		- 10,80
Reuschmedaljer		- 546,00
Beholdning, overført til 1954: I kasse	kr. 192,25	
I bank	- 8 171,79	- 8 364,04
		kr. 52 777,41

1953. Livsvarig medlemmers fond.

		Inntekt	Utgift
1953 1/1 Fondets kapital:			
Obligasjoner	kr. 500,00		
Aksjer	- 4 600,00		
Bankinnskudd	- 8 750,00		
Innbetalt konting. i 1953	- 2 100,00		
Urørlig kapital	kr. 15 950,00		
Renter av bankinnskudd		kr. 225,02	
Renter og inntekter vedr. verdipapirer		- 1 215,40	
Forvaltning av verdipapirer			kr. 6,00
Stempelavgift og bankprovisjon			- 47,50
Overført til ordinært budsjett			- 1 386,92
		kr. 1 440,42	kr. 1 440,42

1953. Berg- og Steinindustriens gavefond.

1953 1/1. Fondets kapital: kr. 25 554,00

Herav disponible til ordin. budsjett	kr. 5 554,00	
Renter for 1953	- 390,04	
Overf. disp.kapital til ord.budsjett		kr. 5 554,00
Overf. renter —»—		- 390,04
	kr. 5.944,04	kr. 5 944,04

Urørlig kapital kr. 20 000,00.

Regnskapet revidert av T. Gjelsvik og T. Strand, Oslo 16/1—1954.

Regnskapet ble godkjent.

Reuschmedaljen ble tildelt *Steinar Skjeseth* for hans arbeide «On the Lower Didymograptus Zone (3b) at Ringsaker, and Contemporaneous Deposits in Scandinavia».

Etter styrets anbefaling ble en enige om at planene om en metamorfosekongress et av de kommende år burde skrinlegges, da en ikke hadde fått tilstrekkelig økonomisk støtte fra staten for budsjettåret 1954/55. I ordskiftet deltok I. Rosenqvist, B. Dietrichson, S. Føyn og formannen.

Valg:

Formann: *Chr. Oftedahl.*
Viseformann: *L. Størmer.*
Sekretær: *R. Selmer-Olsen.*
Redaktør: *N.-H. Kolderup* (dessuten representant for Bergens Geol. Klubb).

Styremedlemmer: *J. Dons.*
E. Kiil
Just Gjessing.
Th. Vogt (*Trondheims* Geol. Klubb).

Reuschmedalje-komite: *S. Føyn, I. Rosenqvist* og det nye styres formann, *Chr. Oftedahl.*

Revisorer: *T. Gjelsvik* og *T. Strand.* m/varamenn *T. Vinsnes* og *G. Holmsen.*

A. Granli anmodes om å fortsette sin virksomhet som forretningsfører etter samme betingelser.

Styremedlemmene i Berg- og Steinindustriens Gavefond ble gjenvalgt. Disse er *C. Bugge, O. Holtedahl* og *G. Holmsen.*

Formannen redegjorde for tidsskriftet. I etterfølgende ordskifte ble der pekt på at tidsskriftet burde ha mer allsidig stoff og at artiklene kunne være mer kortfattet. I ordskiftet deltok: T. Gjelsvik, P. Holmsen, Chr. Oftedahl, N.-H. Kolderup, N. Spjeldnæs, O. Holtedahl og formannen.

Der ble reist forslag av formannen om en godtgjørelse oppad begrenset til kr. 1 000,— til dekning av utlegg til ekstrahjelp o.l. i forbindelse med redaksjonsarbeidet. Midlene skulle disponeres etter nærmere overenskomst mellom styret og redaksjonen. Dette ble vedtatt; i diskusjonen deltok: Chr. Oftedahl, I. Rosenqvist, P. Holmsen, N.-H. Kolderup og formannen.

Møte 351 torsdag 25. februar 1954.

Tilstede 21 medlemmer og 2 gjester.

Forsamlingen mintes overing. Olav Norem's bortgang.

Følgende innvalg ble godkjent:

378 John C. Green, p.t. Geologisk Museum, Oslo, foreslått av T. Barth og G. Kullerud.

379 Cand. real. Asbjørn Bakken, Geografisk Institutt, Blindern, foreslått av J. Gjessing og B. Andersen.

Formannen redegjorde for gjesteforelesninger, foreningens kommende møter og representasjon.

Foredrag av prof. *Niels-Henr. Kolderup:* «Litt om bergartene mellom kystbuene i Sogn og Fjordane».

I ordskiftet etter foredraget deltok: Chr. Oftedahl, T. Gjelsvik, B. Dietrichson, T. Strand, I. Rosenqvist, O. Holtedahl og foredragsholderen.

Emnet for foredraget skal behandles i en artikkel som vil bli trykt i et senere nummer av Norsk Geologisk Tidsskrift.

Møte 352 torsdag 18. mars 1954.

Tilstede 28 medlemmer og 14 gjester.

Foredrag av statsgeolog dr. *T. Gjelsvik:* «Moderne malmletingsmetoder i Amerika. Erfaringer fra studiereise høsten 1953».

I diskusjonen etter foredraget deltok N. H. Magnusson, P. Holmsen, T. Eriksson, B. Dietrichson, J. M. Vokes og foredragsholderen.

Foredraget er trykt i Teknisk Ukeblad nr. 29, 1954.

Møte 353 torsdag 1. april 1954.

Tilstede 23 medlemmer og 7 gjester.

Følgende nye medlem ble godkjent:

380 Prof. dr. Sven Gavelin, Mineralogisk Institutt, Stockholms Høgskola, foreslått av H. Neumann og T. Barth.

Spørsmålet om et årsmøte hvert annet år i form av en serie korte foredrag i løpet av et par dager ble fremkastet av formannen. Det ble antydet evt. å holde det første møte på nyåret 1955. I ordskiftet om denne sak deltok T. Barth, O. Holtedahl, H. Holtedahl, B. Dietrichson, T. Gjelsvik, A. L. Rosenlund.

Foredrag av prof. dr. *Paul Michot* (Liege): «Tectonic Structures of the Central Rogaland Area».

Emnet for foredraget skal behandles i en artikkel som vil bli trykt i et senere nummer av Norsk Geologisk Tidsskrift.

Møte 354 torsdag 6. mai 1954.

Tilstede 31 medlemmer og 12 gjester.

Foredrag av prof. *C. E. Wegmann:* «Vestalpene og deres utvikling».

I diskusjonen etter foredraget deltok L. Størmer, B. Dietrichson, C. Bugge, O. Holtedahl, T. Barth og foredragsholderen.

Møte 355 torsdag 14. oktober 1954.

Tilstede 21 medlemmer og 5 gjester.

Følgende nye medlem ble godkjent:

381 Dr. Robert B. Elliott, Department of Geology, The University, Nottingham, England, foreslått av T. Barth og H. Neumann.

Formannen ga en orientering om opplegget for landsmøte i Oslo i slutten av januar 1955.

Foredrag av prof. dr. ing. *R. Gran Olsson:* «Mulige anvendelser av mekanikk på bergartenes deformasjon».

I diskusjonen etter foredraget deltok I. Rosenqvist, W. Werenskiold, S. Föyn, Chr. Oftedahl, A. L. Rosenlund, H. Major, L. Störmer, B. Dietrichson og foredragsholderen.

Møte 356 torsdag 11. november 1954.

Tilstede 22 medlemmer og 8 gjester.

Følgende innvalg ble godkjent:

382 Peter Padget, M. Sc., p.t. Norges geologiske undersøkesle, Sarsgt. 1, Oslo, foreslått av Chr. Oftedahl og R. Selmer-Olsen.

383 Frank Marcus Vokes, M. Sc., p.t. Norges geologiske undersøkelse, Sarsgt. 1, Oslo, foreslått av Chr. Oftedahl og R. Selmer-Olsen.

Valg: Til sakkyndige rådsmedlemmer for Sulitjelmafondets styre ble for termin 1955—57 valgt L. Störmer og I. Oftedahl med varamann T. Strand.

Foredrag av geolog *P. Padget:* «The stratigraphy and structure of the Caledonides of the Birtavarre region, Northern Norway».

I diskusjonen etter foredraget deltok O. Holtedahl, J. Dons, T. Strand, B. Dietrichson, T. Gjelsvik, S. Føyn, Chr. Oftedahl, F. M. Vokes og foredragsholderen.

Emnet for foredraget vil bli behandlet i en av Norges geologkise undersøkelses kommende publikasjoner.

Møte 357 (julemøte) torsdag 9. desember 1954.

Tilstede 32 medlemmer og 21 gjester.

Prof. *O. Holtedahl* holdt minnetale over rektor, dr. O. T. Grønlie.

Forsamlingen mintes overing. P. Alsgaard's bortgang.

Følgende nye medlemmer ble godkjent:

384 overing. Per Bjørn Holmesland, Herøya pr. Porsgrunn, foreslått av Chr. Oftedahl og R. Selmer-Olsen.

385 cand. mag. Markvard Armin Sellevoll, Geologisk Museum, Oslo, foreslått av J. Dons og H. Neumann.

Foredrag av statsgeolog *Per Holmsen:* Trekk av Opdalfeltets geologi». Foredraget var ledsaget av fargelysbilder.

(Referat av foredraget vil bli trykt i neste nummer av Norsk Geologisk Tidsskrift).

Årsmelding fra Bergens Geologiske Klubb 1954.

Klubben har i 1954 hatt 6 møter med foredrag. Der har gjennomsnittlig vært 15 tilhørere.

Det har vært holdt følgende foredrag:

1. februar:	Cand. real. *Erik Mo:* «Om strandflaten».
25. mars:	Professor Dr. *S. E. Hollingworth*, University College, London: «Geological investigations in Gildeskål, Nordland, during the summer 1953».
12. mai:	Cand. real *Anders Kyrkjebø:* Kvartærgeologiske undersøkelser i midtre Sogn».
27. septbr.:	Stud. real. *Inge Bryhni:* «Geologisk ekskursjon i Stavangerfeltet juni 1954». Stud. real. *Finn Skjerlie:* «Geologisk ekskursjon i Egersundfeltet, juni 1954. P. Michot's teori om feltet».
4. oktober:	Professor dr. *N.-H. Kolderup:* Sammenhengen mellom skifre, gneiser og eklogitter i NV-tavlen».
15. desember:	Julemøte. Dosent dr. *Tore Sund:* «Generalplanundersøkelsen for Bergen og Omland». Etter foredraget fest med ektefeller på Geologisk institutt.

GEOLOGNYTT

Norges Geologiske Undersøkelse.

Cand. real *Thor Siggerud* ble 1. juli 1954 ansatt som midlertidig statsgeolog II.

Magister *Martinus G. Oosterom* ble 1. juni 1953 engasjert som midlertidig medarbeider, og 1. juni 1954 ansatt som midlertidig geolog.

Magister *Eero Pehkonen* ble 1. juli 1954 ansatt som midlertidig geolog.

Universitetet i Oslo.

Vitenskapelig assistent ved Mineralogisk institutt, cand. real. *Thor Siggerud* har fått permisjon fra sin stilling til 1. juli 1955. Som vikar fungerer cand. mag. *Jens Hysingjord.*

Cand. mag. *Markvard Armin Sellevoll* er ansatt som assistent ved Mineralogisk-geologisk museums røntgenlaboratorium fra september 1954 til juni 1955.

Stud. real. *Thor Sverdrup* er ansatt som laborant ved samme laboratorium for samme tidsrom.

Cand. mag. *Gerd Liestøl* er ansatt som museumsstipendiat 1953/1954, med plikt til å arbeide ved Mineralogisk-geologisk museum.

Matematisk-naturvitenskapelig embetseksamen med mineralogi-petrografi som hovedfag er i desember 1954 fullført av *Knut S. Heier.* Avhandling: «En geologisk undersøkelse av bergartene og malmforekomstene i Ørsdalen».

Professor dr. *Olaf Holtedahl* er innvalgt som medlem av *Academie Royale de Belgique* og er tildelt *Deutsche Geologische Gesellschaft's Leopold von Busch*-medalje, med hvilken er forbundet æresmedlemskap i selskapet.

MEDLEMSLISTE

à jour november 1954.
[1]: korresponderende medlem.
*: livsvarig medlem.
Tallet i parentes er innvalgsåret.
(S): stifter (18. februar 1905).

*Adamson, Olge J., dr. Frantsebråtveien 3, Vækerø, Oslo (1945).
Ahlmann, Hans W:son, ambassadør. Kgl. svenske ambassade, Meltzer's gate 4. Oslo. (1919).
Andersen, Bjørn, assistent. Geologisk institutt, Blindern, Oslo. (1952).
Andersen, S. A., dr. Studiestrædet 3, København. (1947).
Asklund, Bror, statsgeolog, Sveriges Geologiska Undersökning, Stockholm 50. (1938).
*Bache, Laura, lektor. Eiksbo, vei 509, Eiksmarka, Røa, Oslo (1931).
*Backlund, Helge, professor. Mineralogisk-geologiska Institutionen, Uppsala 1. (1919).
Baker, Donald, B. Sc. Dept. of Geology, Princeton University, Princeton, N. J., U.S.A. (1951).
Bakken, Asbjørn, cand. real. Geografisk Institutt, Blindern, Oslo. (1954).
*Balk, Robert, professor. Box 182 Campus Station, Cororro, N. M., U.S.A. (1933).
*Barth, Tom. F. W., professor. Geologisk museum, Oslo. 45 (1921).
Bergersen, Birger, statsråd. Anton Schjøthsgt. 13, Oslo. (1921).
Bertheau-Hansen, Chr., bergingeniør. Norges geologiske undersøkelse, Oslo 27. (1942).
Birkeland, Tor, lektor. Avaldsnesgt. 36, Stavanger. (1946).
Bjerrum, Lauritz, direktør. Norges geotekniske instutt, Blindern, Oslo. (1952).
*Bjørlykke, Harald, dr. Norsk Bergverk, Christian August's gate 15, Oslo. (1923).
Boughton, Eric. Hay Tor, 921 Harrow Rd., Wembley, Middlesex, England. (1932).
*Broch, Olaf Anton, professor. Dept. of Mineralogy, University of Punjab, Lahore, Pakistan. (1920).
Bruun, B., ingeniør. N.G.U. Geologisk museum, Oslo 45. (1938).
*Braastad, Johan, dr. Postboks 808, Oslo. (1913).
Bugge, Arne, dr. Utsiktsveien 21, Stabekk. (1914).
*Bugge, Carl, direktør. Håkon den gode's vei 12, Vindern, Oslo. (S).

*Bugge, Jens, professor, Norges tekniske høgskole, Trondheim. (1940).
*Bulman, O. M. B., prof. Sedgwick Museum, Cambridge, England. (1951).
*Callisen, Karen, dr. Mineralogisk og Geologisk Museum, Østervoldgade 7, København K. (1917).
Carlson, Fredrik, överingenjör. Sandelsgatan 35, Stockholm. (1919).
*Carstens, Harald, geolog. Saxenborg, Trondheim. (1949).
Caster, Kenneth, professor. Dept. of Geology and Geography, University of Cincinnati, Cincinnati, Ohio, U.S.A. (1953).
*Chapman, Charleton A., professor. University of Illionis, Urbana, Ill.. U.S.A. (1949).
*Chen Kwan Yuan, B. Sc. Geological Institute, National Peking University, Peking, Kina. (1951).
Collini, Bengt, fil.lic. Mineralogisk-geologiska Institutionen, Uppsala, Sverige. (1949).
Craig, H. B., dr. Dept. of Geology, University, Chicago 37, Ill., U.S.A. (1949).
*Dahl, Eilif, cand. real. Botanisk institutt, Blindern, Oslo. (1946).
Dahl, Erling, ingeniør. Skogveien 1, Notodden. (1945).
Dahlström, Elis, fil. lic. Promenaden 17—19, Falun, Sverige. (1945).
Danielsen, Anders, konservator. Botanisk museum, Bergen. (1949).
*Danielsen, D. A.. rektor, Kongensgt. 15, Kristiansand S. (1945).
*Devore, George W., dr. Dept. of Geology, University, Chicago 37, Ill., U.S.A. (1948).
Dietrichson, Brynjulf, bergingeniør. Norges geologiske undersøkelse, Oslo 27. (1917).
Donnay, J. D. H., professor. Johns Hopkins University, Baltimore 18, Maryland, U.S.A. (1937).
*Dons, Johannes A., konservator. Geologisk museum, Oslo 45. (1941).
*Eckermann, Harry von, professor. Edeby pr. Sparreholm, Sverige. (1937).
Egeberg, F. P., bergingeniør. Rådhusgata 5b, Oslo. (1939).
Elliott, Robert B. dr. Department of Geology, The University, Nottingham, England. (1954).
Enkovaara, Antti, magister. Oulainen, Finnland. (1947).
Eriksen, Edv. Andreas, bergingeniør. Uranienborgveien 11c, Oslo. (1945).
*Eskola, Pentti, professor. Min-geol. Inst., Universitet, Helsingfors. (1919).
Espeland, Margaret, B.Sc. Vei 3672, Nordstrandhøgda, Oslo. (1950).
*Falkenberg, Otto, ingeniør. Priorveien 7, Smestad, Oslo. (1914).
Feyling-Hanssen, Rolf, univ.-stip. Geologisk museum, Oslo 45. (1950).
*Fægri, Knut, professor. Botanisk museum, Bergen. (1935).
Færden, Johannes, statsgeolog. Norges geologiske undersøkelse, Oslo 27. (1948).
*Føyn, Sven, direktør. Norges geologiske undersøkelse, Oslo 27. (1932).
Garthus, Torbjørn, lærar. Garthus, Valdres. (1943).
Gavelin, Sven, professor. Mineralogiska Institut, Stockholm's Högskola, Stockholm, Sverige. (1954).

Gillberg, Gunnar, fil. lic. Stockholm Högskola, Stockholm, Sverige. (1952).
*Gjelsvik, Tore, statsgeolog. Evjebakken 18, Sandvika. (1945).
Gjessing, Just, amanuensis. Geografisk institutt, Blindern, Oslo. (1953).
Gjessing, Leiv, læge. Dikemark sykehus, Asker. (1945).
*Gleditsch, Chr., geolog. Bentesgt. 10, Oslo. (1941).
*Green, John, C., B. A. 183 North Main Street, West Hartford, Conn., U.S.A. (1954).
Grennes, Johannes, ingeniør. Statens råstofflaboratorium, Østmarka, Trondheim. (1945).
*Grip, Erland, fil. lic. Boliden, Sverige. (1938).
*Grønlie, Arne, rektor. Mo komm. høgre almenskole, Mo i Rana. (1943).
*Hagemann, Fredrik, cand. mag. Hjelmsgt. 6a, Oslo. (1951).
*Hagner, A. F., professor. Dept. of Geology, University of Illinois, Urbana, Ill., U.S.A. (1947).
Hansen, Kaj, dr. Gammeltoftsgade 16, København K. (1947).
*Harry, W. T., B. Sc. University College, Dundee, Scotland. (1949).
*Hartley, Jack, B. Sc. Department of Geology, University, Leeds 2, England. (1949).
*Hawkes, Leonard, geologist. Bedford College, Regents Park, London N.W. 1. (1915).
*Heber, Gustav, advokat. Oscarsgt. 49. Oslo. (1938).
*Heber, Gustav, bygningsingeniør. Oscarsgt. 46b, Oslo. (1942).
*Heier, K. S., cand. real. Geologisk museum, Oslo 45. (1952).
*Heintz, Anatol, professor. Geologisk museum, Oslo 45. (1926).
*Heintz, Natascha, cand. mag. Presteveien 84, Blommenholm. (1951).
*Heltzen, Anders M., bergmester. Kongsberg Sølvverk. (1941).
Helverschou, Kaare, disponent. Villavegen 9, Frøen, Oslo. (1943).
*Henderson, Donald M., professor. Dept. of Geology, University of Illinois, Urbana, Ill., U.S.A. (1949).
*Henningsmoen, G., konservator. Geologisk museum, Oslo 45. (1941).
Hernes, Ivar, amanuensis. Geologisk institutt, Bergen. (1947).
*Hesse, P. A. Jürgen, bergingenjör. Nynäsvägen 304, Stockholm/Enskede Sverige. (1936).
*Hessland, Ivar, professor. Stockholms Högskola, Stockholm. (1947).
Higazy, R., prof. Faculty of Science, University of Alexandria, Egypt. (1947).
Hjelmquist, Sven, professor. Geologiska Inst., Lund, Sverige. (1949).
Hofseth, Arne, professor. Norges Tekniske Høgskole, Trondheim. (1952).
Holmberg, Sigurd, fil. mag. Lervägen 24, Lund, Sverige. (1953).
*Holmsen, Andreas, bergmester. Bestun, Ullern. (S).
Holmsen, Bjarne, ingeniør. Charlotte Andersens vei 28, Smestad, Oslo. (1941).
*Holmsen, Gunnar, statsgeolog. Skådalen, Oslo. (1908).
*Holmsen, Per, statsgeolog. Norges geologiske undersøkelse, Oslo 27. (1940).
Holtedahl, Hans, førstekonservator. Geologisk institutt, Universitetet i Bergen (1948).

*Holtedahl, Olaf, professor. Geologisk institutt, Blindern, Oslo. (1908).
*Howe, Henry, V., professor. School of Geology, Louisiana State University, Baton Rouge, Louisiana, U.S.A. (1953).
Huseby, Fredrik, cand. real. Geologisk institutt, N. T. H.. Trondheim (1951).
*Høeg, Ove Arbo, professor. Farmasøytisk institutt, Blindern, Oslo. (1924).
Høeg-Omdal, S. K., byråsjef. Utgarveien 12, Jar pr. Oslo. (1945).
*Isachsen, Fridtjov, professor. Geografisk institutt, Blindern, Oslo. (1929).
Iversen, Anker, preparant. Geologisk institutt, N. T. H., Trondheim. (1953).
*Jakhelln, Johanne Hødal, cand. real. United Nations, Box 20, Gr. Central P. O., New York 17, N. Y., U.S.A. (1943).
Jakhelln, Kirsten, fru. Irisvegen 18, Berg, Oslo. (1953).
Jensen, Einar, dr. Villavegen 24b, Rjukan. (1939).
Johansen, Erling, stipendiat. Kråkerøy, Fredrikstad. (1953).
*Kautsky, Gunnar, statsgeolog. Sveriges Geologiska Undersökning, Stockholm 50, Sverige. (1952).
*Kennedy, W. Q., D. Sc., F. R. S., professor. University of Leeds, Leeds 2, England. (1947).
*Kiil, Erling, bergingeniør, Brantenborgveien 2, Slemdal, Oslo. (1922).
*Klompé, Theo., professor. University of Indonesia, Geological Section, Dj. Ganeca 10, Bandoeng, Java, Indonesia. (1947).
Klüver, Emil, ingeniør. Statens toll-laboratorium, Oslo. (1926).
*Kolderup, Niels-Henr., professor, Geologisk institutt, Bergen. (1919).
*Kollerud, Martha, cand. mag. Trondheimsveien 10, Oslo. (1919).
*Krauskopf, K. B., professor. Geol. Dept. Stanford University, Stanford, Cal. U.S.A. (1953).
*Kristoffersen, K., dr. A/S Norsk Jernverk, Nedre Vollgate 8, Oslo. (1941).
*Kullerud, Gunnar, dr. Geophysical Laboratory, 2801 Upton Street, Washington 8, D.C., U.S.A. (1948).
Kulling, Oskar, statsgeolog. Sveriges Geologiska Undersökning. Stockholm 50, Sverige. (1953).
Kvale, Anders, dosent. Geologisk institutt, Bergen. (1936).
Kvalheim, Aslak, ingeniør. Statens råstofflaboratorium, Østmarka, Trondheim. (1944).
Landergren, Sture, dr. Sveriges Geologiska Undersökning, Stockholm 50. (1943)
Landmark, Einar, direktør. Rådhusgt. 5b, Oslo. (1941).
Landmark, Kåre, konservator. Tromsø museum, Tromsø. (1943).
*Larsson, Tollef, cand. real. Engene Fabrikker, Sætre i Hurum. (1945).
Laursen, Dan., lektor. Julius vej 6, Gentofte, København. (1947).
*Lenander, N. E.. direktör. Norrlandsg. 7—9, Stockholm, Sverige. (1914).
Liestøl, Olav, glasiolog. Norsk polarinstitutt, Observatoriegt. 1, Oslo. (1947).
*Lindley, Henry W., dr. Die techn. Hochschule, Wullner Str. 2, Aachen, Tyskland. (1928).
Ljunggren, Pontus, fil. dr. Geologiska Institution, C. T. H., Gibraltarsgatan 5a, Göteborg, Sverige (1952).

Logn, Ørnulf, cand. real. Geologisk institutt N. T. H., Trondheim. (1953).
Lund, Kjell, direktør. A/S Sulitjelma Gruber, Fr. Nansens pl. 6, Oslo. (1938).
*Lund, Lars, mag. sc. Forsvarets forskningsinstitutt, Kjeller pr. Lillestrøm, (1943).
Lund, Worm, bergingeniør. A/S Sydvaranger, Kongensgt. 5, Oslo. (1941).
*Lundby, Sven Erik, arkitekt. Norges byggforskningsinstitutt, Blindern, Oslo. (1937).
Løddesøl, Åsulv, direktør. Det norske myrselskap, Rosenkrantzgt. 8, Oslo. (1938).
Løvaas, Gunnar, bergingeniør. Skorovas Gruber, Skorovatn p. å. (1949).
*Låg, J., professor. Norges landbrukshøgskole, Vollebekk. (1943).
Magnusson, H. N., överdirektör. Vallhallavägen 46, Stockholm. (1937).
*Major, Harald, geolog. Norsk polarinstitutt, Observatoriegt. 1, Oslo. (1944).
Major, Robert, direktør. Norges tekn.-naturv. forskningsråd. Jernbanetorget 2, Oslo. (1941).
Marklund, Nils, fil. lic. Min. geol. Inst., Uppsala 1. (1951).
*Marmo, Vladi, magister. Mineralogisk Institut, Universitetet, Helsingfors, (1949).
*Marstrander, Henning, bergingeniør. 2924 Leland Road, Homewood, Birmingham 9, Alabama, U.S.A. (1917).
*Marthinussen, Marius, lektor. Ski komm. h. almenskole. Ski. (1931).
Mason, Brian, dr. The American Mus. of Nat. History, Central Part West at 79th Street. New York 24. N. Y., U.S.A. (1953).
McCulloh, Thane H., M.Sc. Division of Physical Sciences, University of California, Riverside, Cal., U.S.A. (1951).
Mellis, Otto, dr. Min. Inst., Stockholms Högskola, Stockholm. (1951).
Meyer, S. Smith, direktør, Stordø gruber. (1924).
[1] Michot, Paul, professor. Inst. de Géologie, Université de Liege, Belgia. (1951).
Monsen, Astrid, konservator. Nyhaugsveien 10, Minde pr. Bergen. (1953).
Mortensen, Odd, cand. real. Postboks 519, Bergen. (1938).
Mortenson, Magne, professor. Norges tekniske høgskole, Trondheim. (1948).
Munck, Sole, museumsinspektør. Mineralogisk og Geologisk Museum, Østervoldgade 7, København K. (1948).
*Murray, Grover, E., professor. School of Geology, Louisiana State University. Baton Rouge, Louisiana, U.S.A. (1953).
*Neumann, H., førstekonservator. Geologisk museum, Oslo 45. (1940).
*Noe-Nygaard, Arne, professor. Østervoldgate 7, København K. (1934).
Norin, Erik, professor. Mineralogisk-geologiska Institution, Uppsala 1. (1947),
*Nosow, Edmund, dr. Box 282, Kentucky Geological Survey, Hopkinsville. Kentucky, U.S.A. (1953).
*Nørregaard, E. M., cand. mag. Mineralogisk og Geologisk Museum Østervoldgate 7, København K. (1917).
*Oftedahl, Christoffer, statsgeolog. Festningsv. 6 Stabekk. (1941).
*Oftedal, Ivar, professor. Mineralogisk institutt Blindern, Oslo. (1918).

*Orvin, A. K., bergingeniør. Håkon den godes vei 21, Vindern, Oslo. (1913).
Ottesen, P. O., lensmann. Manger pr. Bergen. (1915).
Padget, Peter, M.Sc. N.G.U. Geologisk Museum, Oslo 45. (1954).
Paulsen, Nils, bergingeniør. Berg, Maridalen, Oslo. (1947).
*Pettersson, Adam, bergingeniør. Lysaker ved Oslo. (1918).
*Poulsen, Arthur O., statsgeolog. Norges geologiske undersøkelse, Oslo 27. (1941).
*Quensel, Percy, professor. Stockholms Högskola, Stockholm. (1916).
*Ramberg, Hans, professor. Dept. of Geology, Univ. of Chicago, Chicago 37, Ill., U.S.A. (1941).
Ramsli, Gunnar, cand. real. Landbruks dept., Victoria terrasse 3, Oslo. (1948).
Rankama, Kalervo, professor. Geologisk Institut, Universitetet, Helsingfors. (1947).
Regnéll, Gerhard, dr. Geologisk-paleontologiska Inst., Lund, Sverige. (1947).
*Rosendahl, Halvor, konservator. Geologisk museum, Oslo 45. (1918).
*Rosenlund, A. L., jernbanegeolog. Drammensveien 103, Oslo. (1912).
Rosenqvist, Ivan Th., dr. Geoteknisk institutt, Blindern, Oslo. (1941).
Ross, Harald N., direktør. Kongsberg sølvverk, Kongsberg. (1947).
Rutherford, G. K., M. Sc., Norges landbrukshøgskole, Vollebekk. (1952).
*Rønning, O., ingeniør. Skorovas Gruber, Skorovatn p. å. (1938).
Sahlin, Anders. ingenjör. Paleontolog. Inst., Uppsala 8, Sverige. (1953).
Samuelsen, Andreas, lektor. Landåsveien 8c, Bergen. (1929).
Sandrea, André Ph. professor. Laboratoire de Minéralogie, Musée Nation. Hist. Natur. Paris V. (1951).
*Scheumann, K. H., professor. Universität Bonn, Königstrasse 67, Bonn a. Rhein, Tyskland. (1928).
Selmer-Olsen, Rolf S., statsgeolog. Norges geologiske undersøkelse, Oslo 27. (1948).
Semb, Gunnar, forsøksleder. Norges landbrukshøgskole, Vollebekk. (1941).
*Siggerud, Thor, cand. real. Mineralogisk institutt, Blindern, Oslo. (1951).
Skjerlie, Finn, stud. mag. scient. Roald Amundsensvei 97, Bergen. (1951).
*Skjeseth, Steinar, statsgeolog. N.G.U. Geologisk museum, Oslo 45. (1949).
Skordal, Asbjørn, geolog. «Vestråt». Elvegaten 18, Trondheim. (1946).
Smaadal, Gerd Vogt, cand. mag. Gyssestadkollen 25, Slependen. (1951).
Smith, H. H., bergingeniør. Drachmannsgatan 2, Bromma, Stockholm. (1925).
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2	korresponderende medlemmer.
105	livsvarige medlemmer.
113	årsbetalende medlemmer.
220	medlemmer.